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WIND SHEAR AND TURBULENCE MONITORING
IN LIVINGSTON, MONTANA

MILESTONE 5 -- FINAL REPORT

VOLUME I

Submitted To:

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AUGUST 1987

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LIVINGSTON WIND SHEAR AND TURBULENCE STUDY

MILESTONE NO. 5

FINAL REPORT

VOLUME I

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EXECUTIVE SUMMARY

The Livingston Wind Shear and Turbulence study was performed by MultiTech for the Montana Department of Natural Resources and Conservation (DNRC), with funds provided by a grant from the Renewable Energy Program. The objective was to obtain and analyze data to define the wind shear and turbulence characteristics of the Livingston bench area, so potential developers would have sufficient information on which to base their siting and engineering decisions. Data were collected at two-minute intervals for a 16-month period at three levels on a 46-meter tower located on the Livingston bench. The data were processed by a datalogger, recorded onto magnetic tape, and sent to MultiTech's Offices in Butte for computer analysis. Monthly wind shear and turbulence statistics have been submitted quarterly to DNRC throughout the course of this project. This final report summarizes these statistics and analyzes the wind shear and turbulence characteristics of the Livingston bench area. Massive amounts of data were collected and analyzed, but the project had numerous meteorological equipment and tower hardware problems.

The turbulence characteristics of the Livingston site were found to be generally favorable and should not discourage future development of the area's wind resources. The wind shear characteristics are of greater concern, and an accurate understanding of these is necessary for potential future developers to ensure machine performance.

1.0 INTRODUCTION

A substantial amount of historical wind monitoring has been performed on the Livingston bench, with the objective of quantifying the available wind resource. In 1979, DNRC contracted MultiTech to perform systematic wind monitoring with a 10-meter meteorological tower. Later that same year, the U.S. Department of Energy (DOE) also contracted with MultiTech to monitor wind energy in the area, which resulted in the designation of Livingston as a MOD-2 candidate site and the initiation of tri-level monitoring on a 45-meter tower. The results of both studies indicated favorable conditions for wind energy development at Livingston and led to the installation of wind machines by several manufacturers.

These machines suffered numerous breakdowns for reasons not fully understood. Potential developers had expressed concern that meteorological conditions may have been the cause of poor machine performance at Livingston, particularly wind shear and turbulence. In response to these concerns, DNRC contracted MultiTech to quantify the wind shear and turbulence characteristics on the Livingston bench. The following sections briefly define wind shear and turbulence phenomena and the physical, environmental, and climatic conditions that contribute to them.

1.1 PHYSICAL AND ENVIRONMENTAL FEATURES AFFECTING WIND SHEAR AND TURBULENCE

Both wind shear and turbulence are strongly affected by natural terrain and man-made features. These factors are often referred to by the term "surface roughness". In general, both wind shear and turbulence tend to increase with increasing surface roughness (Hiester 1981). An example of extreme surface roughness is a downtown urban area with skyscrapers. In this case, the strong frictional effects of the skyscrapers would cause wind speeds near the ground to be much lower than those above the building tops, resulting in a strong wind shear. Similarly, the buildings would induce wake effects and favor the formation of turbulent eddies; they would cause the flow to be less smooth.

At the other extreme is airflow over a flat plains region, or over a calm ocean. In these cases, the surface roughness is very low, so that frictional effects would largely disappear a short distance above the surface. In this case, in the absence of other meteorological factors, wind speed would tend to change slowly with increasing height beyond a short distance above ground. Furthermore, the absence of wake-inducing features would not favor the formation of turbulent eddies, and the magnitude of turbulence would tend to be much less than in a downtown urban area. Intermediate examples include small, rolling hills and flat wooded terrain. In these cases, one would expect the turbulence and wind shear to be greater than that over an ocean, but less than in an

urban area, as the surface roughness is intermediate between these extremes.

The Livingston study area, while located on a relatively flat, open bench, is nearly surrounded by high, steep mountains where the near-surface airflow is largely dictated by terrain features. It was speculated that the rough terrain could at times induce significant surface frictional effects out to the bench area, resulting in strong wind shears. Similarly, the mountainous terrain could favor the formation of turbulent eddies during certain wind regimes. Thus, ample reason existed for concern about wind shear and turbulence phenomena.

1.2 RELATION OF METEOROLOGICAL FACTORS TO WIND SHEAR AND TURBULENCE

In addition to terrain features, wind shear and turbulence also are strongly related to meteorological conditions. A very important factor affecting wind shear is atmospheric stability, defined by the rate of change of temperature with height (Thresher 1984). The following table shows a scheme used by the Nuclear Regulatory Commission (Atomic Energy Commission 1972).

TABLE 1-1. DEFINITION OF ATMOSPHERIC STABILITY CLASSES

Classification	Pasquill Stability Category	T100m – T10m
Very unstable	A	$<-1.7^{\circ}C$
Moderately unstable	B	-1.7 to $-1.5^{\circ}C$
Slightly unstable	C	-1.5 to $-1.3^{\circ}C$
Neutral	D	-1.3 to $-0.4^{\circ}C$
Slightly stable	E	-0.4 to $+1.3^{\circ}C$
Moderately stable	F	$+1.3$ to $+3.6^{\circ}C$
Very stable	G	$>+3.6^{\circ}C$

The relation of wind shear to stability tends to be well defined. In unstable and neutral conditions high momentum air is mixed down near the surface. This reduces the amount of wind shear across a typical wind machine rotor disk (normally located at least 20 meters above ground) because much of the shear occurs in the lowest 10 meters of the atmosphere. During stable conditions, by contrast, the mixing of high momentum air down to the ground is less. Thus, less of the wind shear occurs in the lowest 10 meters, resulting in greater shear across a rotor disk than would occur during neutral or unstable conditions (Hiester 1981). This relationship could be affected by other factors, such as wind speed.

The impact of stability on turbulence previously had not been widely studied and was investigated during this project. One type of meteorological phenomenon well known for producing extremely gusty conditions with high winds is the thunderstorm. Because a weather observation station is located at the Livingston airport,

this study provided an opportunity to study turbulence and wind shear during thunderstorm conditions. The airport observers record the beginning and ending times of all precipitation episodes, including thunderstorms. Wind shear and turbulence data collected during thunderstorm episodes were examined to determine whether they differed from data obtained during other periods. The relationship between wind shear and turbulence also was investigated during this study.

Extensive analyses of the results are presented in Section 3.0. However, a brief summary of meteorological conditions that affect wind shear and turbulence at Livingston, based on the study results, is given below. The meteorological conditions that cause increases in wind shear tend to decrease turbulence, and vice versa.

TABLE 1-2. SUMMARY OF FACTORS AFFECTING WIND SHEAR AND TURBULENCE

Factor	Effect on Wind Shear	Effect on Turbulence
Low wind speeds	Decrease	Increase
High wind speeds	Increase	Decrease
Daytime hours	Decrease	Increase
Nighttime hours	Increase	Decrease
Southerly and northerly winds	Decrease	Increase
Southwesterly and easterly winds	Increase	Decrease
Stable conditions	Decrease	Increase
Unstable conditions	Decrease	Increase
Thunderstorms	Insignificant	Insignificant

1.3 DEFINITION OF TURBULENCE AND WIND SHEAR CHARACTERISTICS AND STATISTICS

1.3.1 Turbulence

Turbulence, with respect to wind in an atmospheric flow, can be considered as random fluctuations in wind speed about a mean value. These fluctuations are often described as gusts, and can be defined and interpreted in several ways. As an example, consider an atmospheric flow with a mean magnitude, x, of 5 meters per second (ms^{-1}) over a period of two minutes, with variations of up to ^{1} ms^1, x^* during that period. One way of defining the turbulent component of this flow would be to simply report the x^* value of 1 ms^{-1}. The turbulent component could also be expressed as a fraction of the mean flow, x^*/x, in this case 0.20.

A more useful way of describing gustiness for wind-energy potential is in terms of the standard deviation of the wind speed over a given averaging period (Kelly 1984). For example, knowing that the mean wind speed (determined vectorially) over a two-minute period was 5 ms^{-1}, with a standard deviation of 0.5 ms^{-1}, would be useful information about the gustiness of the wind.

Two types of turbulence intensity satistics were calculated: alongwind turbulence intensity (ALT) and acrosswind turbulence intensity (ACT). ALT is defined as the standard deviation of wind speed along the mean wind vector divided by the mean vector wind speed. ACT is defined as the standard deviation of the wind speed

perpendicular to the mean wind vector divided by the mean vector
wind speed.

Turbulence intensities are calculated as follows:

$$ACT = \frac{[(A-B^2)(C^2)+(D-C^2)(B^2)-2(E-(B)(C))(B)(C)]^{1/2}}{B^2 + C^2}$$

$$ALT = \frac{[(A-B^2)(B^2)+(D-C^2)(C^2)+2(E-(B)(C))(B)(C)]^{1/2}}{B^2 + C^2}$$

Variables A-E are defined as follows:

    Let U = Mean easterly wind component

        V = Mean northernly wind component

Then A = Average of U^2

    B = Average of U

    C = Average of V

    D = Average of V^2

    E = Average of (U)(V)

Previous studies have indicated that the magnitude of the
acrosswind turbulence intensity is generally less than that of the
alongwind turbulence intensity (Akins 1978). However, at
Livingston the opposite was usually found to be true, except during
high wind speeds.

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1.3.2 Wind Shear

Wind shear is defined as the change in wind speed with height. Two types of wind shear statistics, termed absolute wind shear (AWS) and the power law exponent (PWS), were calculated for this study. AWS is simply the difference in absolute wind speed between two heights. For example, if the wind speed at 9 meters were 8 ms^{-1} and the speed at 46 meters were 10 ms^{-1}, the AWS would be 2 ms^{-1} (Elliott 1984).

PWS is an attempt to logarithmically define the change in wind speed with height using the following equation:

$$V(Z_1) = V(Z_0) \left(\frac{Z_1}{Z_0}\right)^P$$

where $V(Z_1)$ = Wind speed at height Z_1

$V(Z_0)$ = Wind speed at height Z_0

P = Power law exponent (PWS).

Using the above example, $V(Z_1)$ = 10 ms^{-1}, $V(Z_0)$ = 8 ms^{-1}, Z_1 = 46 meters, and Z_0 = 9 meters. Solving for P, one obtains a value of 0.145.

2.0 MONITORING SYSTEM DESIGN

The design of the monitoring system was dictated by the data requirements to adequately define wind shear and turbulence at Livingston. At the onset of the project, several individuals who are actively involved in wind monitoring and development were contacted to determine how wind shear and turbulence data should be obtained to be useful to a developer. They recommended that both alongwind and acrosswind turbulence intensity be measured at three tower levels and reported at 2-minute intervals (Akins 1984). They also recommended that maximum instantaneous wind shears over these same 2-minute intervals be measured. These requirements necessitated a very sophisticated data collection system, described in the following sections.

2.1 DATA COLLECTION AND ANALYSIS PROCEDURES

Monitoring was performed at heights of 9 meters, 30 meters, and 46 meters above ground level on the 46 meter tower located on the Livingston bench. Wind data were collected by wind speed and direction sensors at each level, and processed by a data logger to obtain the needed raw wind statistics at 2-minute intervals. The data were dumped onto cassette tapes, forwarded weekly to MultiTech's office in Butte, and read into the mainframe computer. These statistics then were used to calculate the required wind shear and turbulence data for each 2-minute period. Additionally, atmospheric stability was monitored by temperature sensors located

2-1

at the 9 meter and 46 meter tower levels. All data were printed
out in daily reports and checked for validity; any data suspected
to be invalid were flagged and not used in any subsequent data
analyses.

The massive amount of data collected during this study was stored
both in its raw form and as frequency counts in joint distributions
to facilitate easier access and manipulation. Table 2-1 shows an
example of this second data storage technique: joint frequency
counts of alongwind turbulence intensity and wind speed at the 30-
meter level for the month of September 1985. Each number within
the array represents the number of coincident occurrences during
the month of both wind speed and alongwind turbulence intensity
falling within their respective ranges. For example, the number in
the top left corner of the array, 83, indicates the frequency of
simultaneous occurrences of wind speeds between 0 and 2 ms^{-1} and
alongwind turbulence intensities of between 0 and 5% during the
month of September. Monthly arrays of this type were generated for
the following combinations of variables, at all three tower levels:

1.   Turbulence Intensity and: Time of Day
                                      Wind Speed
                                      Wind Direction
                                      Atmospheric Stability
                                      Wind Shear

Joint Frequency Distribution Table
SEP, 1985

TURBULENCE_INTENSITY_ALONG_WIND_30M versus WIND_SPEED_30M (2nd Parameter)

TURBULENCE_INTENSITY_ALONG_WIND_30M Range

2nd Param Range (M/S) >= / <	<0.05	<0.10	<0.15	<0.20	<0.25	<0.30	<0.35	<0.40	<0.45	<0.50	<0.55	<0.60	<0.65	<0.70	<0.75	<0.80	<0.85	<0.90	<0.95	Avg	Std Dev
0.0 – 2.0	83	372	182	125	48	30	16	23	12	4	8	3	2	5	2	2	2	2	17	0.19	0.40
2.0 – 4.0	175	659	607	313	140	78	39	16	13	8	7	1	1	3	6	3	1	1	12	0.15	0.16
4.0 – 6.0	133	859	561	177	60	17	10	8	1	0	0	0	1	0	0	1	0	0	0	0.11	0.06
6.0 – 8.0	129	1197	817	152	24	5	2	1	0	0	0	0	0	0	0	0	0	0	0	0.10	0.04
8.0 – 10.0	108	1291	724	112	22	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0.04
10.0 – 12.0	51	961	609	70	10	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0.03
12.0 – 14.0	17	593	360	50	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0.03
14.0 – 16.0	4	233	106	15	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09	0.03
16.0 – 18.0	2	65	28	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.08	0.03
18.0 – 20.0	0	8	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0.02
20.0 – 22.0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.10	0.04
22.0 – 24.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
24.0 – 26.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
26.0 – 28.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
28.0 – 30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
30.0 – 32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
32.0 – 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
34.0 – 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
36.0 – 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
38.0 – 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
40.0 – 42.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
42.0 – 44.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
44.0 – 46.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
46.0 – 48.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
48.0 – 50.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00

WIND_SPEED_30M

	<0.05	<0.10	<0.15	<0.20	<0.25	<0.30	<0.35	<0.40	<0.45	<0.50	<0.55	<0.60	<0.65	<0.70	<0.75	<0.80	<0.85	<0.90	<0.95
Average	5.7	8.0	7.6	5.6	4.3	3.4	3.0	2.8	2.1	2.4	2.3	1.8	1.8	2.6	2.1	3.5	3.4	2.1	1.9	2.0
Std Dev	3.2	3.6	3.5	3.4	2.9	2.2	1.3	1.3	0.6	0.8	0.6	0.4	0.3	1.1	0.5	3.0	1.4	0.7	0.5	0.5

Table Statistics
Total Count: 12541
Monthly Count: 21600
Percent Recovery: 58.52

TABLE 2-1

2.   Wind Shear and: Time of Day
                                         Wind Speed
                                         Wind Direction
                                         Atmospheric Stability
                                         Maximum Wind Shear
                                         (During the same 2-minute
                                         period)
                                         Maximum Wind Speed
                                         (During the same 2-minute
                                         period)

3.   Alongwind Turbulence Intensity and Acrosswind Turbulence
      Intensity

4.   Wind Speed and Wind Direction

Since a primary objective of this study was to define the influence
of other meteorological parameters on wind shear and turbulence,
this type of data storage system generally worked very well. Most
of the subsequent data analyses involved various manipulations of
these arrays. Additionally, statistics on the duration of wind
shear and turbulence intensities above given levels were generated.

Finally, a variety of wind speed, wind direction, and wind energy
statistics were generated for each month, as listed below:

   · Daily average wind speed and direction for each tower level;

   · Monthly average wind speed and direction for each tower level;

   · Hourly average wind speed and direction for each tower level;

   · Daily and monthly average wind energy for each tower level;
      and

· Wind speed and direction joint frequency distribution for each tower level.

These statistics were correlated with historical data collected at Livingston between 1980 and 1982 (see Section 3.6).

2.2 MONITORING PARAMETERS AND EQUIPMENT

Wind direction, wind speed, and temperature were monitored directly approximately every second; average values of these parameters were calculated by the datalogger and recorded onto magnetic tape every two minutes. A variety of other wind statistics required for wind shear and turbulence calculations also were calculated by the datalogger every two minutes. The actual wind shear and turbulence values were computed by MultiTech's mainframe computer in Butte. Table 2-2 lists the parameters that were monitored during this study. Parameters that were used to calculate wind shear statistics are denoted by an asterisk (*); those used to calculate turbulence are marked with a plus (+).

The monitoring of these parameters, particularly the parameters used to calculate turbulence, required a very sophisticated datalogging system. The data logger chosen for this project was a Campbell Scientific Model CR21X. In addition to accommodating a large number of sensor inputs, it had the extensive in-field algebraic programming capabilities necessary to monitor the parameters needed to calculate the wind shear and turbulence

TABLE 2-2. PARAMETERS MONITORED AT LIVINGSTON

DIRECTLY MONITORED PARAMETERS

Parameter	Sample Frequency	Tower Levels Monitored
Wind Direction	1 second	9m, 30m, 46m
Wind Speed	1 second	9m, 30m, 46m
Temperature	2 minutes	9m, 46m

INDIRECTLY MONITORED PARAMETERS (CALCULATED BY DATALOGGER)

Parameter	Sample Frequency	Reporting Frequency	Tower Levels
Wind Direction Standard Deviation	1 second	2 minutes	9m, 30m, 46m
Wind Speed Average*	1 second	2 minutes	9m, 30m, 46m
Wind Speed Maximum	1 second	2 minutes	9m, 30m, 46m
U-Component Average+	1 second	2 minutes	9m, 30m, 46m
U^2-Component Average+	1 second	2 minutes	9m, 30m, 46m
V-Component Average+	1 second	2 minutes	9m, 30m, 46m
V^2-Component Average+	1 second	2 minutes	9m, 30m, 46m
U-V Component Average+	1 second	2 minutes	9m, 30m, 46m
Wind Shear Maximum*	1 second	2 minutes	9m-46m, 9-30m, 30m-46m
Temperature Average	1 second	2 minutes	9m, 46m

PARAMETERS CALCULATED BY MAINFRAME COMPUTER[1]

Parameter	Tower Levels
Alongwind Turbulence Intensity	9m, 30m, 46m
Acrosswind Turbulence Intensity	9m, 30m, 46m
Wind Shear Average	9-30m, 9m-46m, 30m-46m
Atmospheric Stability (Delta T)	9m-46m
Wind Direction Average	9m, 30m, 46m

[1] These parameters were all calculated for 2-minute averaging periods.

* Used for wind shear calculations.

+ Used for turbulence calculations.

statistics.   Campbell Scientific Model CS101 sensors were used to monitor temperature at 9 meters and 46 meters, necessary for the calculation of atmospheric stability.

The selection of wind sensors was also of critical importance, as the measurement of turbulence and wind shear requires sensors that respond quickly to changes in wind direction and speed.   To meet this objective, Met One Model 010 and Model 020 sensors were used to monitor wind speed and wind direction.   Both are made to respond quickly to changes in the wind and have distance constants of approximately 5 feet.   This statistical term commonly is used to describe the responsiveness of wind sensors, and it is the distance travelled by the air after a sharp-edged gust has occurred before the sensors react to 63% of the change in wind speed and direction. Met One sensors were chosen because of their high performance and reliability on several previous projects.   Originally, plastic anemometer cups were used because of their high responsiveness; however, large amounts of data were lost because of cups blowing off during extremely windy periods.   Efforts were made to correct this problem, first by reinforcing the plastic cups with epoxy, and finally by replacing the plastic cups with metal cups.   None of these corrective measures solved the problem, and the data loss caused by the problem was an impediment throughout the project.

Specifications for the equipment used in the project are shown in Appendix A.

3.0 RESULTS AND DISCUSSION

3.1 DEVELOPMENT OF STATISTICS

The monthly joint frequency count arrays described in Section 2.1 provided the basis for most of the wind shear and turbulence data analyses performed for this project. Four principal types of analyses were generated: annual joint frequency count arrays, joint frequency distribution arrays, percent frequency distribution arrays, and cumulative percent frequency distribution arrays.

First, most of the monthly arrays were added together by type to obtain joint frequency counts for the entire data period. For example, joint frequency counts of alongwind turbulence intensity and wind direction at 30 meters for the entire data period (annual joint frequency count arrays) were generated by adding together all of the monthly joint frequency counts of these two parameters. This step was necessary to reduce the data base to a manageable size as, during the period monitoring was performed, nearly 1,000 of these monthly joint frequency count tables were generated.

Second, while the joint frequency counts were useful for determining the number of occurrences of ranges of variables, the percentage of the time given conditions occurred also was desired. Therefore, the joint frequency count arrays were used to generate joint frequency distribution arrays, showing the percentage of the time that different combinations of variables were present.

Since a primary objective of this study was to examine the variation of turbulence and wind shear with other meteorological variables, these joint frequency distribution arrays were in turn used to generate two other types of arrays. The first, percent frequency distribution arrays, were calculated to show the behavior of wind shear and turbulence with other meteorological variables. For example, the array combining alongwind turbulence intensity and wind speed at 9 meters gives a frequency distribution of alongwind turbulence intensity at 9 meters for each wind speed range that occurred at 9 meters. Similarly, cumulative percent frequency arrays were generated. For the above example, this type of array shows the percentage of the time that the alongwind turbulence intensity at 9 meters exceeded given values, for given wind speed ranges.

Examples of each array type are shown in Tables 3-1 through 3-4. All annual array tables that were generated are presented in Appendix E.

The monthly arrays and annual arrays, respectively, were used to calculate frequency distributions of wind shear and turbulence for each level by month and for the entire data period. The wind speed, wind direction, and wind energy statistics already had been reduced to a manageable form for the quarterly analyses; final analysis required some compilation and summarization of statistics, but no additional computer data reduction, except for the generation of seasonal and annual wind roses.

TURBULENCE INTENSITY RANGE, PERCENT

WIND SPEED RANGE M/S > <=	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	>=95
0.0 2.0	1634	5708	1511	557	274	149	89	58	55	38	33	24	16	26	14	15	13	17	5	121
2.0 4.0	3070	10480	7859	4703	2352	1308	735	517	358	288	202	152	99	92	88	75	57	44	45	545
4.0 6.0	2595	9427	6307	2751	1046	423	203	94	65	29	17	7	7	11	7	5	2	3	4	16
6.0 8.0	3044	12964	6704	1918	584	144	62	20	8	9	1	2	1	0	1	0	1	2	1	3
8.0 10.0	2708	13773	6121	1364	315	79	17	4	3	3	1	1	0	0	0	1	0	1	0	0
10.0 12.0	1712	10835	4339	795	168	46	10	4	0	0	0	1	0	0	0	0	0	0	0	1
12.0 14.0	1049	7603	2669	472	87	22	6	2	0	0	0	0	0	0	0	0	0	0	0	0
14.0 16.0	576	4159	1440	269	61	8	2	0	0	1	0	1	0	0	0	0	0	0	0	0
16.0 18.0	260	2596	1030	185	41	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0
18.0 20.0	160	1925	673	100	15	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.0 22.0	138	1522	400	51	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22.0 24.0	98	775	250	32	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24.0 26.0	53	473	98	9	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
26.0 28.0	23	216	40	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28.0 30.0	7	36	22	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30.0 32.0	2	13	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32.0 34.0	2	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34.0 36.0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36.0 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38.0 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40.0 42.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
42.0 44.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44.0 46.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46.0 48.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48.0 50.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

JOINT FREQUENCY COUNT OF ALONGWIND TURBULENCE INTENSITY (46 METERS) AND WIND SPEED (46 METERS) AT LIVINGSTON, MONTANA.

DATA PERIOD SEP 1985 - NOV 1986

TABLE 3-1

TURBULENCE INTENSITY RANGE, PERCENT

WIND SPEED RANGE M/S	<5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	>95
0.0 - 2.0	1.00	3.48	0.92	0.34	0.17	0.09	0.05	0.04	0.03	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.07
2.0 - 4.0	1.87	6.39	4.79	2.87	1.42	0.80	0.45	0.32	0.22	0.16	0.12	0.04	0.06	0.06	0.05	0.05	0.02	0.03	0.03	0.33
4.0 - 6.0	1.58	5.75	3.85	1.68	0.64	0.26	0.12	0.06	0.04	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
6.0 - 8.0	1.86	7.91	4.09	1.17	0.36	0.05	0.04	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8.0 - 10.0	1.65	8.40	3.73	0.83	0.19	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10.0 - 12.0	1.04	6.61	2.65	0.48	0.10	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.0 - 14.0	0.64	4.64	1.63	0.29	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14.0 - 16.0	0.35	2.54	0.88	0.16	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.0 - 18.0	0.16	1.58	0.63	0.11	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18.0 - 20.0	0.10	1.17	0.41	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20.0 - 22.0	0.08	0.93	0.24	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.0 - 24.0	0.06	0.47	0.15	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24.0 - 26.0	0.03	0.29	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26.0 - 28.0	0.01	0.13	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.0 - 30.0	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.0 - 32.0	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32.0 - 34.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34.0 - 36.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.0 - 38.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38.0 - 40.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40.0 - 42.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42.0 - 44.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44.0 - 46.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46.0 - 48.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48.0 - 50.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

JOINT FREQUENCY DISTRIBUTION OF ALONGWIND TURBULENCE INTENSITY (46 METERS) AND WIND SPEED (46 METERS) AT LIVINGSTON, MONTANA.
(VALUES SHOWN ARE PERCENT OF TOTAL OBSERVATIONS FALLING WITHIN CORRESPONDING WIND SPEED AND TURBULENCE RANGES)

DATA PERIOD SEP 1979 - 19

TABLE 3-2

TURBULENCE INTENSITY RANGE, PERCENT

WIND SPEED RANGE M/S		0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80-85	85-90	90-95	>=95
0.0	<= 2.0	15.78	54.14	14.59	5.36	2.65	1.72	0.86	0.56	0.50	0.37	0.35	0.23	0.15	0.25	0.14	0.14	0.13	0.16	0.05	1.17
2.0	<= 4.0	9.28	31.60	27.77	14.22	7.11	3.96	2.22	1.56	1.06	0.87	0.51	0.46	0.30	0.28	0.27	0.23	0.17	0.13	0.14	1.65
4.0	<= 6.0	11.27	40.95	27.40	11.95	4.54	1.84	0.88	0.41	0.28	0.13	0.07	0.03	0.03	0.05	0.03	0.02	0.01	0.01	0.02	0.07
6.0	<= 8.0	11.95	50.90	26.32	7.53	2.29	0.57	0.24	0.08	0.03	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
8.0	<= 10.0	11.10	56.47	25.10	5.59	1.29	0.32	0.07	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
10.0	<= 12.0	9.56	60.49	24.23	4.44	0.94	0.26	0.05	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.0	<= 14.0	8.81	63.83	22.41	3.96	0.73	0.18	0.05	0.02	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14.0	<= 16.0	8.84	63.83	22.10	4.13	0.94	0.12	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.0	<= 18.0	6.31	62.99	24.99	4.49	0.99	0.17	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18.0	<= 20.0	5.56	66.93	23.40	3.48	0.52	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20.0	<= 22.0	6.51	71.63	18.88	2.41	0.24	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.0	<= 24.0	8.48	67.04	21.63	2.77	0.09	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24.0	<= 26.0	6.33	74.37	15.41	1.42	0.16	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26.0	<= 28.0	8.10	76.06	14.08	1.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.0	<= 30.0	10.61	54.55	33.33	1.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.0	<= 32.0	11.76	76.47	11.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32.0	<= 34.0	28.57	42.86	28.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34.0	<= 36.0	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.0	<= 38.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
38.0	<= 40.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
40.0	<= 42.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
42.0	<= 44.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
44.0	<= 46.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
46.0	<= 48.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
48.0	<= 50.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

PERCENT FREQUENCY DISTRIBUTION OF ALONGWIND TURBULENCE INTENSITY(46 METERS) BY WIND SPEED(46 METERS) RANGES AT LIVINGSTON, MONTANA.
VALUES OF "." ARE SHOWN FOR WIND SPEED RANGES THAT NEVER OCCURRED.
DATA PERIOD SEP 1985 - NOV 19--

TABLE 3-3

TURBULENCE INTENSITY, PERCENT

WIND SPEED RANGE (M/S)	>=0	>=5	>=10	>=15	>=20	>=25	>=30	>=35	>=40	>=45	>=50	>=55	>=60	>=65	>=70	>=75	>=80	>=85	>=90	>=95
0.0 - 2.0	99.99	84.22	29.11	14.52	9.14	6.50	5.06	4.20	3.64	3.11	2.74	2.42	2.19	2.04	1.79	1.65	1.51	1.38	1.22	1.17
2.0 - 4.0	99.99	90.72	59.03	35.26	21.04	13.93	9.97	7.75	6.18	5.10	4.23	3.62	3.16	2.86	2.58	2.32	2.09	1.92	1.78	1.65
4.0 - 6.0	99.99	88.73	47.77	20.37	6.42	3.88	2.04	1.16	0.75	0.47	0.34	0.27	0.24	0.21	0.16	0.13	0.11	0.10	0.09	0.07
6.0 - 8.0	99.99	88.05	37.15	10.82	3.29	1.00	0.44	0.19	0.11	0.08	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.01
8.0 - 10.0	99.99	88.90	32.43	7.33	1.74	0.45	0.13	0.06	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
10.0 - 12.0	99.99	90.44	29.95	5.72	1.28	0.35	0.09	0.03	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.0 - 14.0	99.99	91.19	27.36	4.95	0.99	0.26	0.08	0.03	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14.0 - 16.0	99.99	91.16	27.33	5.23	1.10	0.17	0.05	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16.0 - 18.0	99.99	93.69	30.70	5.70	1.21	0.22	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18.0 - 20.0	99.99	94.44	27.50	4.10	0.63	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20.0 - 22.0	99.99	93.49	21.66	2.78	0.38	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.0 - 24.0	99.99	91.52	24.48	2.85	0.09	0.00	0.16	0.16	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24.0 - 26.0	99.99	91.67	17.30	1.89	0.47	0.31	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26.0 - 28.0	99.99	91.90	15.85	1.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28.0 - 30.0	99.99	89.39	34.85	1.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30.0 - 32.0	99.99	88.24	11.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32.0 - 34.0	99.99	71.43	28.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34.0 - 36.0	99.99	99.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36.0 - 38.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
38.0 - 40.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
40.0 - 42.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
42.0 - 44.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
44.0 - 46.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
46.0 - 48.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
48.0 - 50.0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

CUMULATIVE PERCENT FREQUENCY OF ALONGWIND TURBULENCE INTENSITY(46 METERS) BY WIND SPEED(46 METERS) RANGE
AT LIVINGSTON, MONTANA
(VALUES OF 0.00 ARE SHOWN FOR WIND SPEED RANGES THAT NEVER OCCURRED)

DATA SET ...

TABLE 3-4

3.2 TURBULENCE INTENSITY

Alongwind and acrosswind turbulence intensity data were collected at heights of 9 meters, 30 meters, and 46 meters every 2 minutes during this study. The following sections present and discuss the summarized turbulence data, beginning with a general discussion of the turbulence characteristics at Livingston. Next, turbulence characteristics are related to time of day, wind speed, wind direction, atmospheric stability, wind shear, and thunderstorm conditions. An overall assessment of the turbulence environment at Livingston is presented in Section 3.7, Conclusions.

3.2.1 General Turbulence Characteristics

In general, the turbulence intensity at Livingston can be classified as low to moderate, based on a classification system developed by Baker et al. 1986. In this system, turbulence intensities below 10% are classified as "low"; those between 10 and 20% as "moderate"; and those over 20% as "high". The average alongwind turbulence intensity (ALT) for the period of study ranged from 12.9% at the 9-meter level down to 11.7% at the 46-meter level. Average acrosswind turbulence intensities (ACT) ranged from 15.1% at 9 meters down to 13.9% at 46 meters. The Baker classification system is based on the standard deviation of the wind speed divided by the average wind speed, a statistic which is nearly identical to the alongwind turbulence intensity. The acrosswind turbulence intensity is somewhat related to the standard

deviation of wind direction, but does not lend itself to any existing system of strength classification. However, Baker's system is used in this report for data comparison purposes.

Table 3-5 presents average turbulence intensities for each month that data were collected; several trends can be observed. The first is that turbulence intensities tend to decrease with height, particularly between 9 and 30 meters. This is to be expected, as ground-induced mechanical turbulence effects normally decrease logarithmically with height. This also explains why differences in turbulence between 9 and 30 meters are much more apparent than those between 30 and 46 meters. A second trend is that of higher turbulence during late spring and summer months, and lower turbulence during the winter, which reflects the role of solar heating in generating atmospheric turbulence and also the effects of wind speed, discussed in Section 3.2.3. Finally, in nearly all cases the ACT is higher than the corresponding ALT. This is surprising, as a previous study in New Mexico had found the opposite to be true (Akins 1984). The ACT observed in New Mexico was similar to that in Livingston, but the ALT intensities were much higher in New Mexico. However, the monthly average ALT at Livingston never exceeded the midrange (15%) of the moderate category defined by Baker.

Frequency distributions of ALT and ACT are presented in Table 3-6 and Figures 3-1 and 3-2. Intensities between 5 and 15% are the most common, occurring about 75% of the time; the higher turbulence

TABLE 3-5. MONTHLY AVERAGE TURBULENCE INTENSITY
AT LIVINGSTON, MONTANA
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

Average Turbulence Intensity

Month*	Alongwind 9 Meters	Acrosswind 9 Meters	Alongwind 30 Meters	Acrosswind 30 Meters	Alongwind 46 Meters	Acrosswind 46 Meters
March	12.3	13.2	10.8	12.1	10.0	11.0
April	12.0	13.3	11.2	12.6	11.3	12.8
May	14.2	16.7	13.1	16.1	12.7	15.6
June	13.8	17.8	13.5	17.3	12.8	16.8
July	14.0	18.0	12.5	16.1	12.2	15.9
August	13.8	18.6	13.3	17.5	13.3	17.5
September	12.4	14.1	11.3	12.8	11.5	13.2
October	12.9	14.8	12.7	13.4	12.0	14.3
November	11.1	12.0	10.0	11.1	10.7	10.9
December	12.5	12.3	11.0	11.3	10.4	11.2
Annual	12.9	15.1	11.9	14.0	11.7	13.9

* Because of equipment malfunctions, no turbulence data were collected
  during the months of January or February.

TABLE 3-6. FREQUENCY DISTRIBUTION OF TURBULENCE INTENSITY
AT LIVINGSTON, MONTANA
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

Turbulence Intensity Range Percent	Percent Frequency					
	Alongwind 9 Meters	Acrosswind 9 Meters	Alongwind 30 Meters	Acrosswind 30 Meters	Alongwind 46 Meters	Acrosswind 46 Meters
0-5	4.78	2.66	8.23	6.42	10.45	9.52
5-10	39.62	40.41	49.18	46.03	50.33	46.15
10-15	36.69	31.21	26.95	24.10	24.08	21.63
15-20	11.25	11.36	8.29	9.60	8.06	8.76
20-25	3.71	5.23	3.16	4.79	3.02	4.60
25-30	1.50	2.74	1.43	2.74	1.34	2.70
30-35	0.71	1.74	0.74	1.67	0.69	1.70
35-40	0.40	1.11	0.43	1.12	0.43	1.13
40-45	0.27	0.76	0.33	0.74	0.30	0.75
45-50	0.17	0.53	0.20	0.55	0.22	0.59
50-55	0.12	0.40	0.16	0.39	0.16	0.44
55-60	0.08	0.29	0.13	0.31	0.12	0.32
60-65	0.07	0.24	0.09	0.22	0.08	0.27
65-70	0.05	0.22	0.06	0.18	0.08	0.20
70-75	0.05	0.14	0.05	0.15	0.07	0.17
75-80	0.05	0.12	0.05	0.12	0.06	0.13
80-85	0.03	0.10	0.05	0.11	0.05	0.11
85-90	0.03	0.08	0.04	0.09	0.04	0.10
90-95	0.3	0.07	0.04	0.07	0.03	0.07
95<	0.37	0.61	0.41	0.60	0.42	0.67
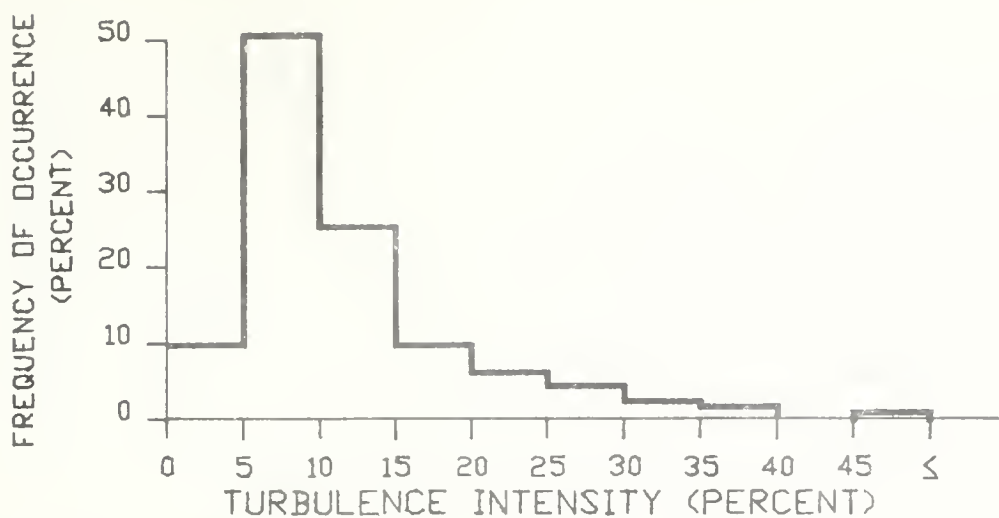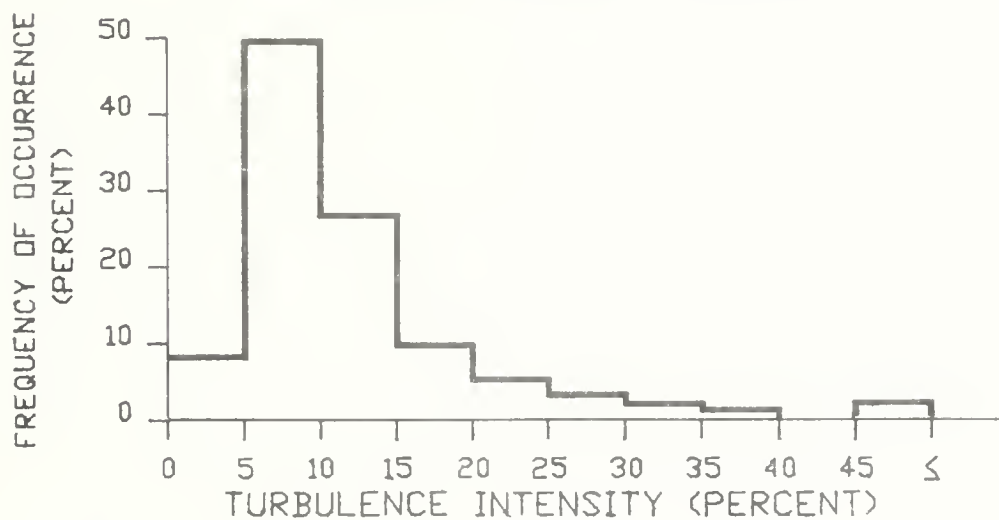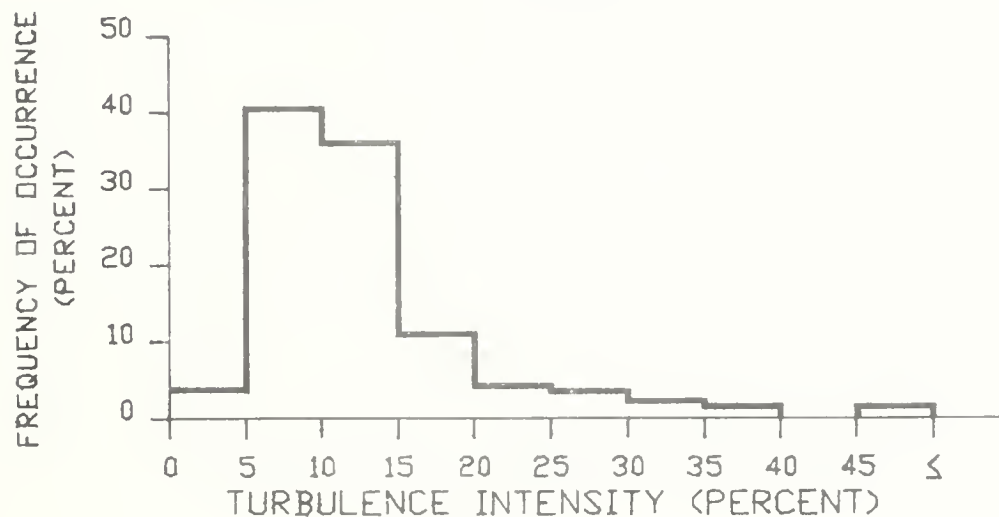
FIGURE 3-1

FREQUENCY DISTRIBUTION OF ALONGWIND TURBULENCE INTENSITY
AT LIVINGSTON, MONTANA FOR:

A) 46 METERS   B) 30 METERS   C) 9 METERS

DATA PERIOD SEP. 1985 – NOV. 1986   A-7DW50101

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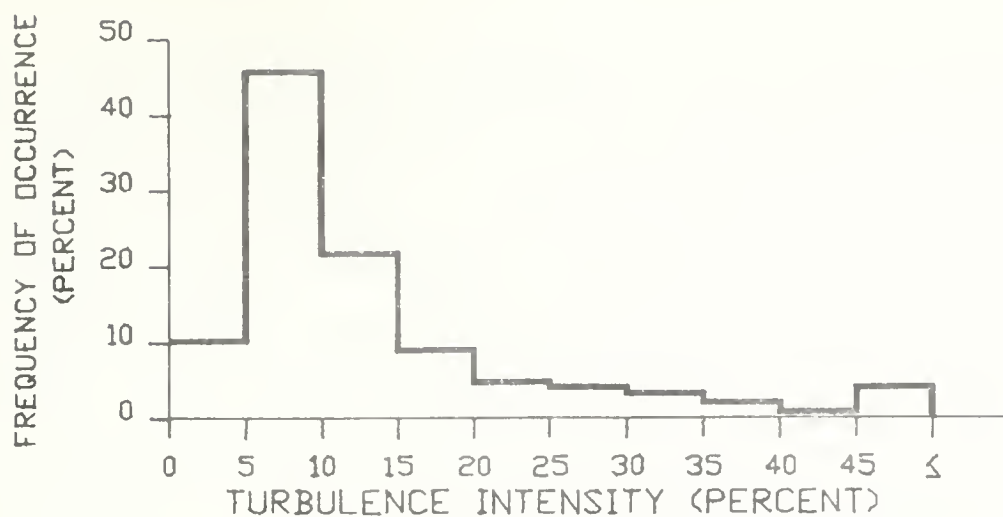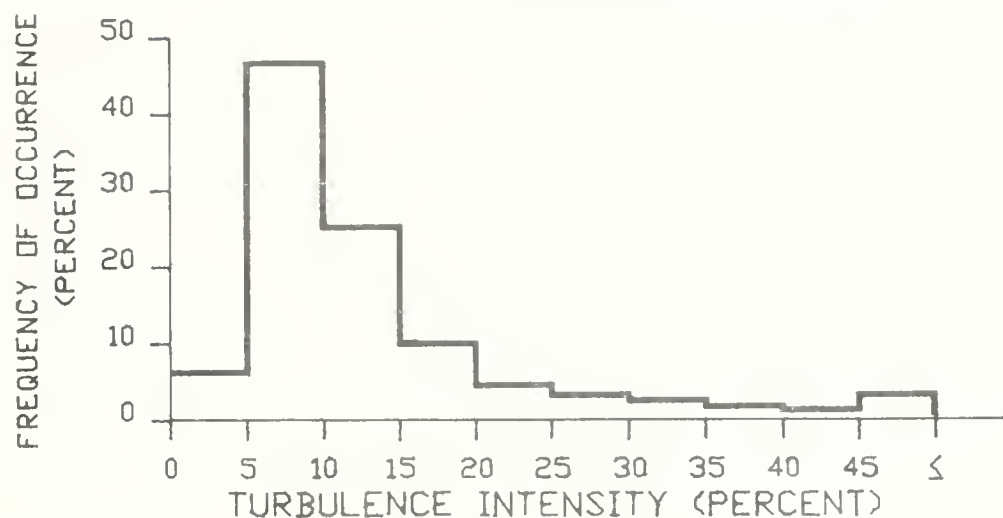
FIGURE 3-2

FREQUENCY DISTRIBUTION OF ACROSSWIND TURBULENCE INTENSITY
AT LIVINGSTON, MONTANA FOR:

A) 46 METERS   B) 30 METERS   C) 9 METERS

DATA PERIOD SEP. 1985 - NOV. 1986   A-7DW50102

3-12

intensity ranges occur very infrequently. The higher ALT levels become slightly more common with increasing height, although the average ALT levels decrease. Possible reasons for this behavior are discussed later in this report. Overall, the higher ACT ranges occur more often than the corresponding ALT ranges; this follows the pattern of ACT generally being higher than ALT. Figures 3-3 and 3-4 show the frequency of occurrence of ALT and ACT above specified values. Less than 10% of the ALT's are above 20%, Baker's "high" range; roughly 1% of the ALT's exceed 50%. At 30 meters and 46 meters, fewer than half of the measured ALT's exceeded Baker's "low" range.

An additional analysis is presented in Tables 3-7 and 3-8, showing the percentage of turbulence intensities within each of Baker's categories by month. In several months (generally late spring and summer) ALT's in the high range occurred over 10% of the time; they were least common during the late fall and winter, occurring less than 5% of the time in several months. ACT shows a much greater month-to-month variation, with high ranges becoming much more frequent during the summer months. At 9 meters for example, ACT's above 10% occurred only 6.9% of the time in November, but 27.0% of the time in August. All three tower levels exhibit fairly consistent month-to-month behavior for both ALT and ACT.

Based on these results, several conclusions can be drawn regarding the turbulence characteristics at Livingston. Turbulence is generally low to moderate, with less than 10% of the ALT's falling
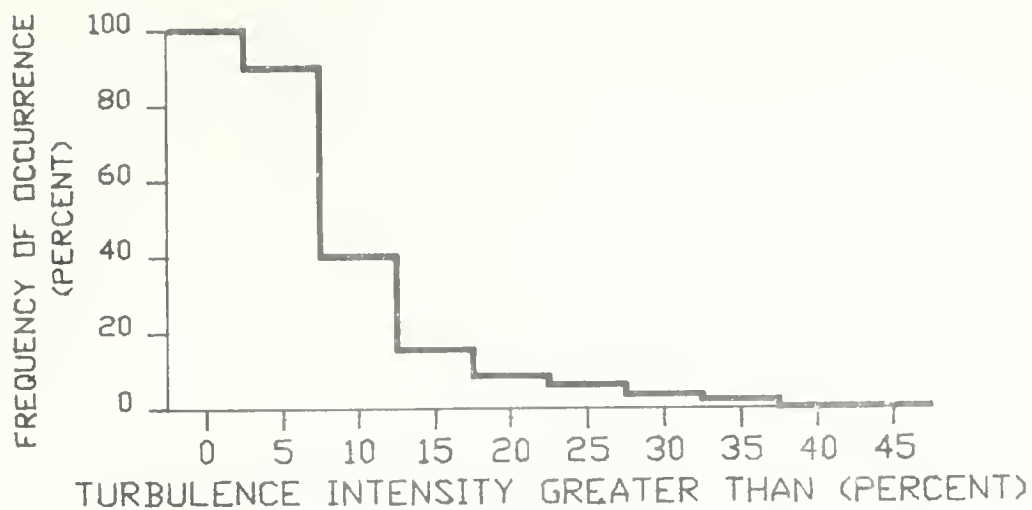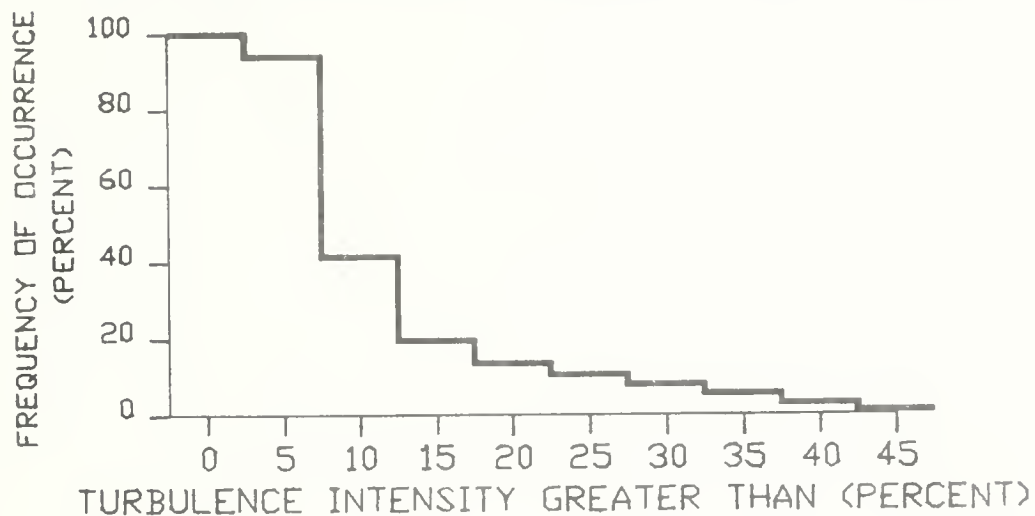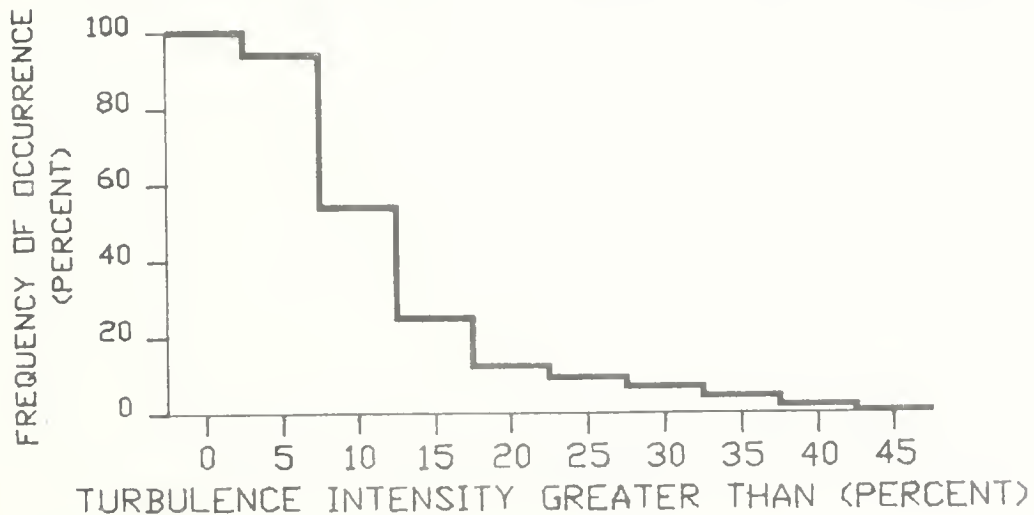
FIGURE 3-3

CUMULATIVE FREQUENCY DISTRIBUTION OF ALONGWIND TURBULENCE
INTENSITY AT LIVINGSTON, MONTANA FOR:

A) 46 METERS   B) 30 METERS   C) 9 METERS

DATA PERIOD SEP. 1985 - NOV. 1986

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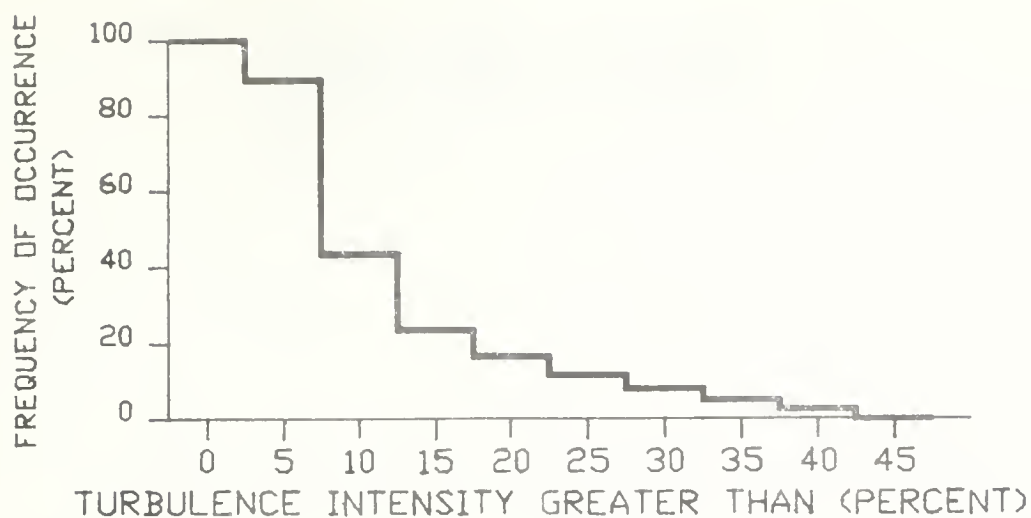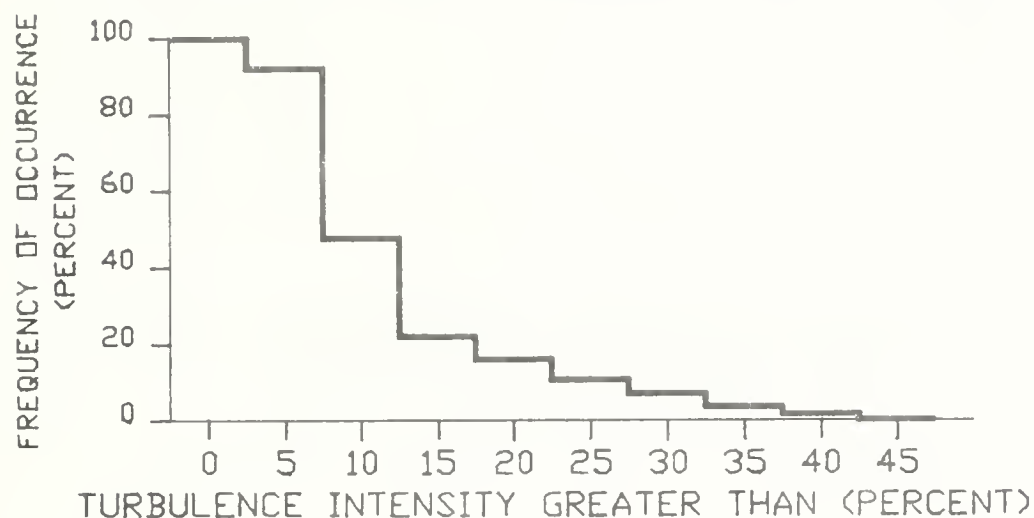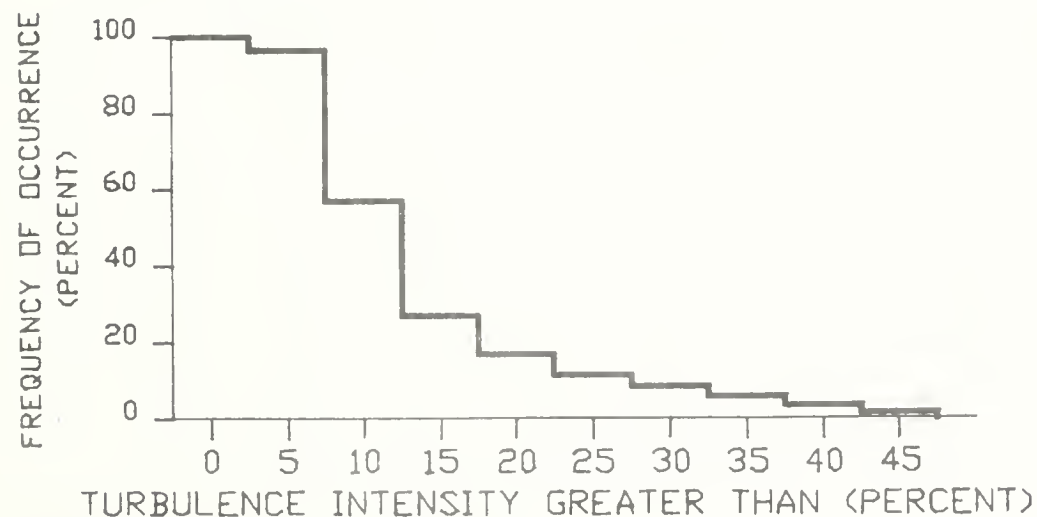
FIGURE 3-4

CUMULATIVE FREQUENCY DISTRIBUTION OF ACROSSWIND TURBULENCE
INTENSITY AT LIVINGSTON, MONTANA FOR:

A) 46 METERS   B) 30 METERS   C) 9 METERS

DATA PERIOD SEP. 1985 - NOV. 1986

A-7DV50108

TABLE 3-7. FREQUENCY OF OCCURRENCE OF ALONGWIND TURBULENCE INTENSITY
RANGES AT LIVINGSTON, MONTANA BY MONTH
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

L = LOW (<10%)   M = MODERATE (10% - 20%)   H = HIGH (>20%)

Month*	Alongwind 9 Meters			Alongwind 30 Meters			Alongwind 46 Meters		
	L	M	H	L	M	H	L	M	H
March	39.7	54.5	5.8	58.4	37.0	4.6	62.3	33.5	4.2
April	47.6	45.4	7.0	61.4	29.8	6.8	63.1	30.4	6.5
May	39.7	50.0	11.3	52.7	36.7	10.6	56.2	33.7	10.1
June	41.1	48.9	10.0	54.6	35.7	9.7	56.8	34.0	9.2
July	38.2	50.5	11.3	51.6	38.7	9.7	54.8	36.4	8.8
August	43.3	43.7	13.0	51.1	37.6	11.3	50.7	39.0	10.3
September	42.8	51.4	5.8	59.6	35.3	5.1	60.6	33.6	5.8
October	45.3	47.0	7.7	53.8	35.8	10.4	61.0	30.9	8.1
November	56.0	40.3	3.7	66.8	29.6	3.5	69.7	25.9	4.4
December	37.6	55.4	7.0	57.5	37.2	5.3	62.8	32.3	4.9

TABLE 3-8. FREQUENCY OF OCCURRENCE OF ACROSSWIND TURBULENCE INTENSITY
RANGES AT LIVINGSTON, MONTANA BY MONTH
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

L = LOW (<10%)   M = MODERATE (10% - 20%)   H = HIGH (>20%)

Month*	Acrosswind 9 Meters			Acrosswind 30 Meters			Alongwind 46 Meters		
	L	M	H	L	M	H	L	M	H
March	40.4	50.3	9.3	54.3	37.9	7.8	58.0	35.2	6.8
April	48.8	40.1	11.1	57.3	31.7	11.0	58.6	30.0	11.4
May	36.9	43.7	19.4	45.1	36.0	18.9	49.6	32.1	18.3
June	31.0	47.4	21.6	42.0	38.0	20.0	43.9	35.5	20.6
July	29.8	46.8	23.4	40.9	39.0	20.1	44.2	36.0	19.8
August	30.1	42.9	27.0	37.3	38.5	24.2	40.7	35.9	23.4
September	58.0	30.9	11.1	55.8	34.0	10.2	58.4	30.5	11.1
October	57.0	28.7	14.3	54.9	30.4	14.7	55.8	29.4	14.8
November	50.4	32.7	6.9	67.1	25.6	7.3	70.1	24.4	5.5
December	50.8	39.8	9.4	62.7	28.7	8.6	62.1	29.6	8.3

*Because of equipment malfunctions, no turbulence data were collected
 during the months of January or February.

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in the high range. The turbulence intensity generally decreases with height, with most of the decrease occurring between 9 and 30 meters. Turbulence intensity is highest in the late spring and summer, and lowest during the late fall and winter months. Finally, ACT tends to be higher than ALT, particularly during the summer months.

3.2.2 Variation of Turbulence With Time of Day

Average values of ALT and ACT were calculated for each hour of the day using the entire data set, to determine whether a significant relation exits. The results are shown in Table 3-9 and Figure 3-5. Both ALT and ACT show fairly consistent behavior at all three tower levels, with the highest values occurring in mid-day and the lowest during the early evening hours. This diurnal phenomenon probably is related to both solar heating and the formation of the nocturnal temperature inversion. The peak in ALT and ACT during the mid-day hours probably coincides with the peak in solar heating, when solar-induced turbulence is at its maximum. Also, the minimum in ALT and ACT observed during the early evening coincides with the nocturnal temperature inversion's formation period. These inversions tend to form abruptly (although their dissolution may take several hours), resulting in a very stable atmosphere near the ground immediately after their formation and therefore lower turbulence. The reasons for the increase in turbulence between early evening and midnight are not readily apparent.

TABLE 3-9. AVERAGE TURBULENCE INTENSITY BY HOUR OF THE DAY
AT LIVINGSTON, MONTANA
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

Hour of The Day	Alongwind 9 Meters	Acrosswind 9 Meters	Alongwind 30 Meters	Acrosswind 30 Meters	Alongwind 46 Meters	Acrosswind 46 Meters
01	11.7	14.2	10.8	13.3	11.0	13.7
02	11.6	14.4	10.4	13.2	10.6	13.5
03	12.0	14.8	11.1	13.9	10.8	13.8
04	11.9	14.8	11.2	14.0	11.1	13.9
05	11.9	14.4	11.1	13.6	11.1	13.4
06	11.8	13.7	11.6	13.8	11.3	13.6
07	12.0	14.4	12.0	14.7	11.6	14.2
08	12.4	14.7	11.6	14.2	11.3	14.1
09	12.4	14.9	11.5	14.4	11.4	14.3
10	13.1	15.4	12.0	14.5	11.9	14.7
11	13.6	16.3	12.4	15.0	11.8	14.4
12	13.6	15.7	12.2	14.3	11.6	13.8
13	13.7	15.4	12.3	14.1	11.5	13.5
14	13.8	15.5	12.5	14.3	11.7	13.6
15	13.4	14.7	12.2	13.8	11.4	13.0
16	13.0	14.4	12.0	13.6	11.1	12.7
17	12.2	13.2	11.3	12.6	10.5	11.7
18	11.4	12.2	10.5	11.6	9.9	10.9
19	10.7	11.7	10.1	11.2	9.7	11.1
20	10.7	11.8	9.9	11.0	9.7	10.9
21	10.9	12.3	10.1	11.3	10.0	11.3
22	11.3	12.9	10.4	11.9	10.4	11.9
23	11.5	13.8	10.7	12.6	11.0	13.2
24	11.8	14.4	11.4	13.9	11.4	14.2
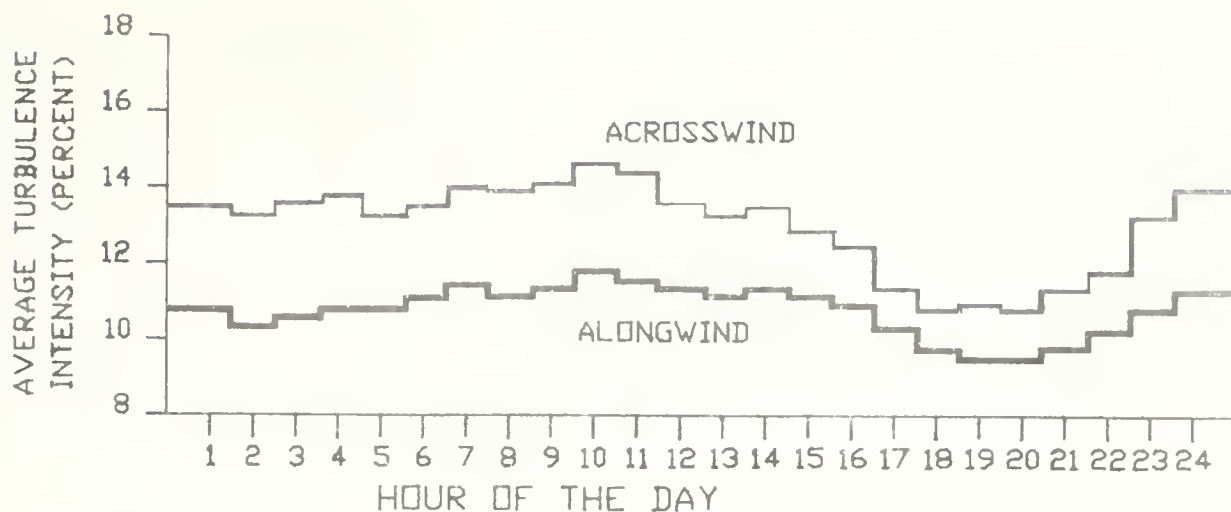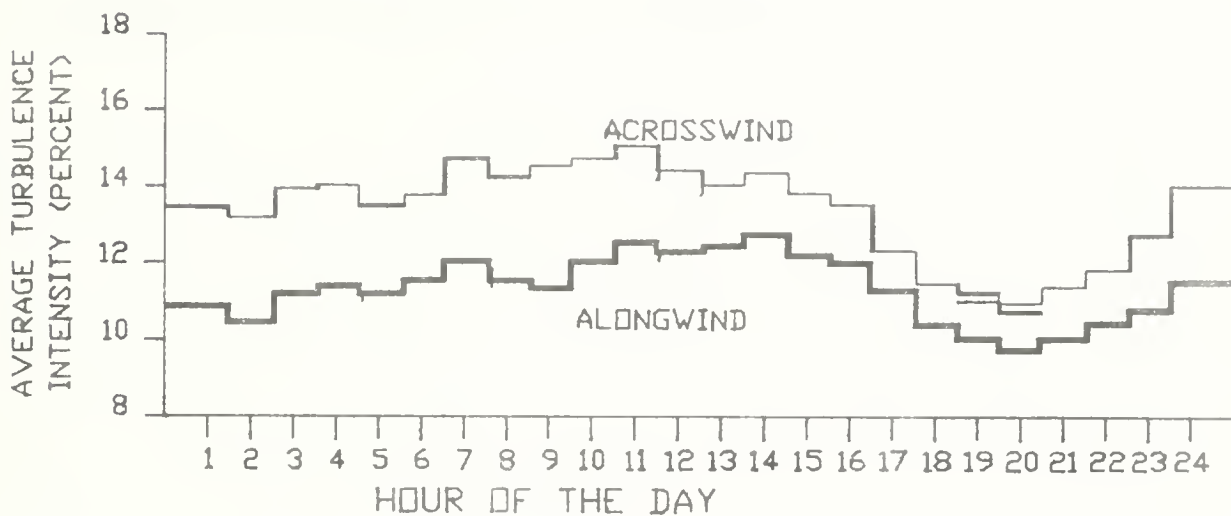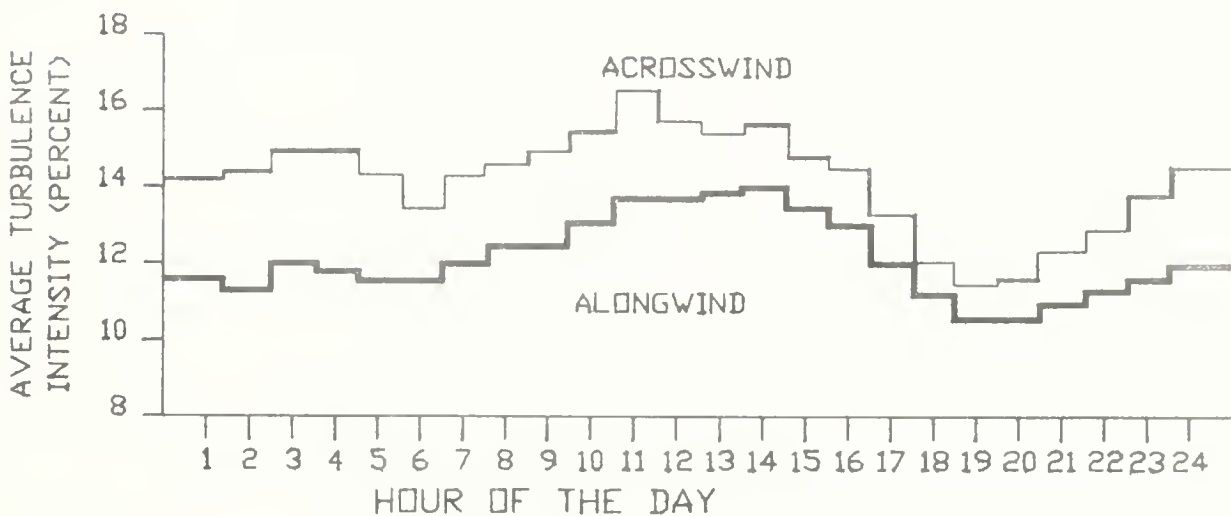
FIGURE 3-5

AVERAGE TURBULENCE INTENSITY BY TIME OF
DAY AT LIVINGSTON, MONTANA FOR:

A) 46 METERS   B) 30 METERS   C) 9 METERS

DATA PERIOD SEP. 1985 – NOV. 1986

A-7DW50109

These diurnal variations in turbulence are greatest at 9 meters, where solar heating of the ground has its greatest impact, although all three levels show a very similar trend. Similarly, more variation is observed for ACT than for ALT, although both fluctuate in nearly identical patterns. While the ALT at 9 meters varies considerably with time of day, even its highest average value of 13.8% is well below the midrange of Baker's moderate category.

3.2.3 Variation of Turbulence with Wind Speed

Before any formal data analyses were performed, a very strong relationship between turbulence intensity and wind speed was observed. This correlation dictated a fairly extensive analysis of the effects of wind speed on turbulence intensity. Table 3-10 shows the average ALT and ACT for each 2 ms^{-1} wind speed range observed at Livingston. ALT and ACT are shown to react somewhat differently to increases in wind speed.

ALT is fairly low in the 0-2 ms^{-1} wind speed range, and peaks in the 2-4 ms^{-1} range. At speeds above 6 ms^{-1} the average ALT remains nearly constant at each level, ranging from approximately 11.5% at 9 meters to 8.8% at 46 meters. This distribution is favorable, as it shows that the windy conditions of concern to developers are usually accompanied by low turbulence intensities, especially at typical wind machine hub heights (e.g., 30 meters).

TABLE 3-10. AVERAGE TURBULENCE INTENSITY BY WIND SPEED RANGES
AT LIVINGSTON, MONTANA
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

Average Turbulence Intensity

Wind Speed (m/s)	Alongwind 9 Meters	Acrosswind 9 Meters	Alongwind 30 Meters	Acrosswind 30 Meters	Alongwind 46 Meters	Acrosswind 46 Meters
0-2	9.6	21.9	13.2	25.8	11.4	24.4
2-4	14.8	20.6	15.9	19.9	16.3	22.3
4-6	11.6	12.2	10.9	12.1	11.3	12.3
6-8	11.4	11.2	9.6	10.0	9.6	9.8
8-10	11.4	10.9	9.4	9.5	9.1	9.2
10-12	11.4	10.5	9.4	9.3	8.9	8.9
12-14	11.5	10.2	9.5	9.0	8.7	8.5
14-16	11.8	10.0	9.7	9.0	8.8	8.4
16-18	11.5	9.4	9.9	8.8	9.1	8.3
18-20	11.3	8.9	9.6	8.2	8.8	7.8
20-22	11.4	8.5	9.3	7.6	8.4	7.4
22-24	11.2	8.1	9.3	7.0	8.4	6.9
24-26	10.8	8.2	9.2	6.9	8.1	7.0
26-28	12.9	7.9	9.8	6.8	8.0	6.4
28-30	12.5	17.5	10.1	7.3	8.8	6.1
30-32			9.2	6.9	7.5	6.0
32-34			7.5	12.5	7.5	5.4
34-36					7.5	12.5

The response of ACT to increases in wind speed is quite different. ACT is at its maximum in the lowest speed range, 0-2 ms^{-1}, and shows a continual decrease with increasing wind speed. It does not exhibit as much of the leveling behavior shown by ALT for high wind speeds. Another feature is that at speeds above 10 ms^{-1}, the ACT was actually lower than the ALT although the ACT is higher on the average. This indicates that higher wind speeds are accompanied by smaller variations in wind direction. Consistent with results discussed previously, both ALT and ACT generally decreased with height except at very low wind speeds (below 4 ms^{-1}). The decrease with height generally becomes more pronounced with increasing wind speeds, particularly for ALT. For example, the average ALT for wind speeds between 6 and 8 ms^{-1} is 11.4% at 9 meters and 9.6% at 46 meters; the respective values for wind speeds between 22 and 24 ms^{-1} are 11.2% and 8.4%.

The ALT data also were analyzed to determine the percentage of intensities falling within each strength category for each wind speed range. The results are presented in Figure 3-6. The most striking feature is the almost complete absence of high turbulence intensities at speeds above 10 ms^{-1}, particularly at 46 meters. At 30 and 46 meters, the majority of ALT's at speeds above 5 ms^{-1} fall within the low range. At 9 meters, values in the medium range are more common, although these are generally in the low end of the medium range. High values occur over 5% of the time only at speeds below 6 ms^{-1}, which are not generally of concern to wind
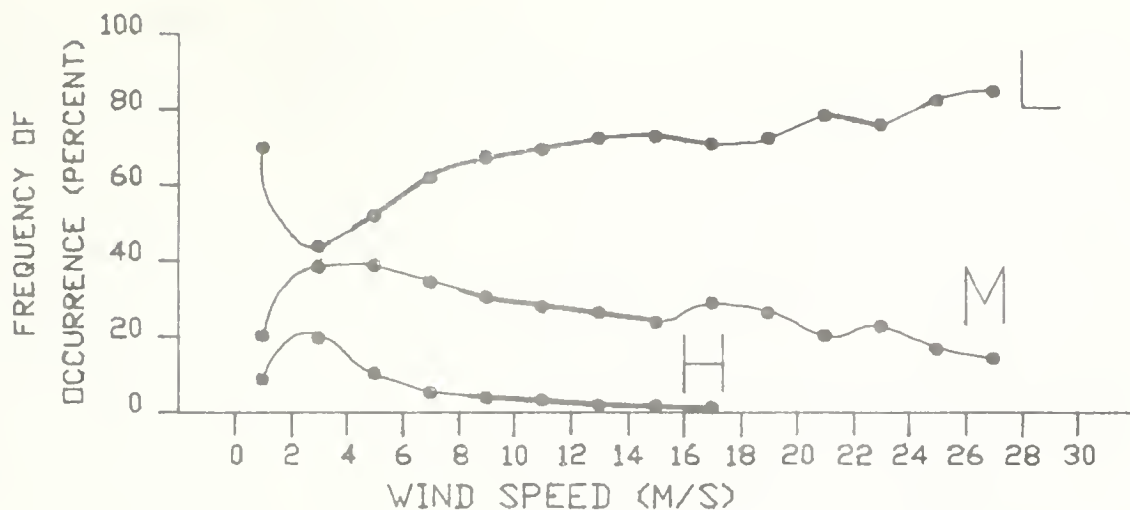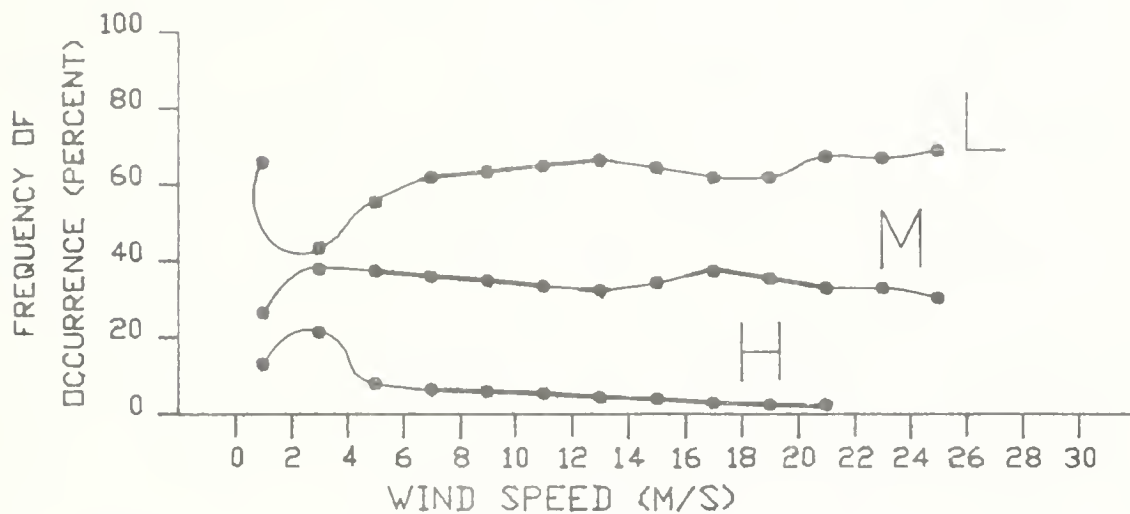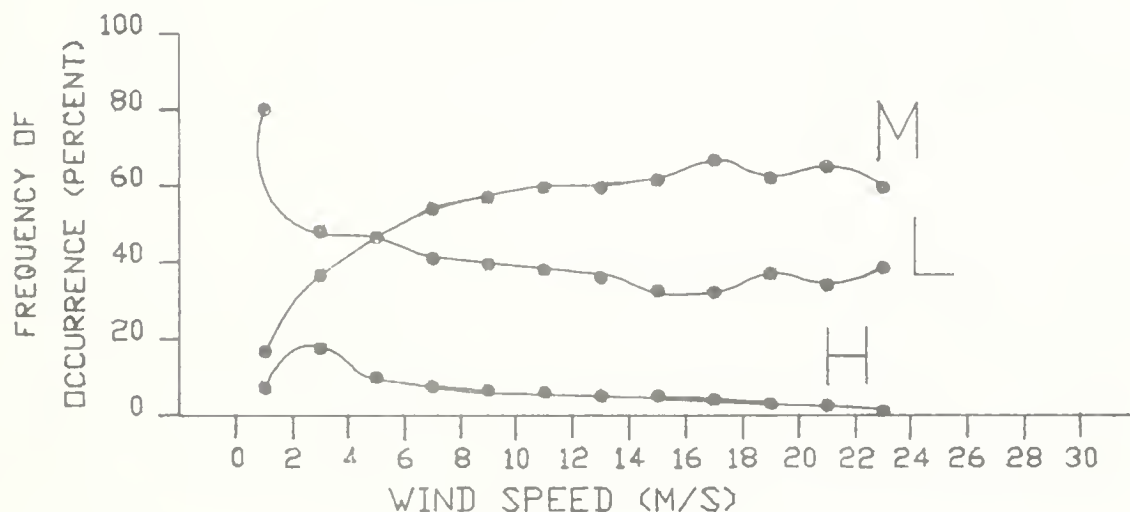
FIGURE 3-6

PERCENT FREQUENCY OF OCCURRENCE OF ALONGWIND TURBULENCE
INTENSITIES VERSUS WIND SPEED:
L= LOW (0-10%)   M=MODERATE (10-20%)   H=HIGH (≥20%)
A) 46 METERS   B) 30 METERS   C) 9 METERS

DATA PERIOD SEP. 1985 - NOV. 1986   A-7DW50110

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developers. This analysis reinforces previous indications of a generally favorable turbulence regime at Livingston.

Finally, cumulative frequency distributions of ALT and ACT were plotted for wind speed ranges of 2-4 ms^{-1}, 6-8 ms^{-1}, and 12-14 ms^{-1} for the 30-meter level. These speeds were selected because they represent approximate values of non-operating speeds, cut-in speeds and rated speeds for commonly used wind-powered generators. The results are presented in Figures 3-7 and 3-8. Each curve shows the percentage of the time that turbulence intensities exceeded given values for the indicated wind speed range. These curves reinforce the finding that high turbulence intensities occur almost exclusively with low wind speeds, which are not generally of concern to developers. For the speed ranges of 6-8 ms^{-1} and 12-14 ms^{-1}, ALT intensities in the high range (>20%) occur less than 5% of the time; these intensities exceed 30% less than 1% of the time. Cumulative frequencies for higher wind speed categories were not plotted, because they would essentially superimpose on curve C. The results shown for the 12-14 ms^{-1} range are descriptive of the ALT behavior at higher wind speeds.

Several conclusions can be drawn regarding the effects of wind speed on turbulence intensity. The first is that high ALT and ACT intensities are generally associated with low wind speeds, and that ALT and ACT intensities are usually low during high wind speeds. Secondly, ACT is generally lower than ALT during the higher wind speeds, although it is higher on the average. Third, both ALT and

3-24
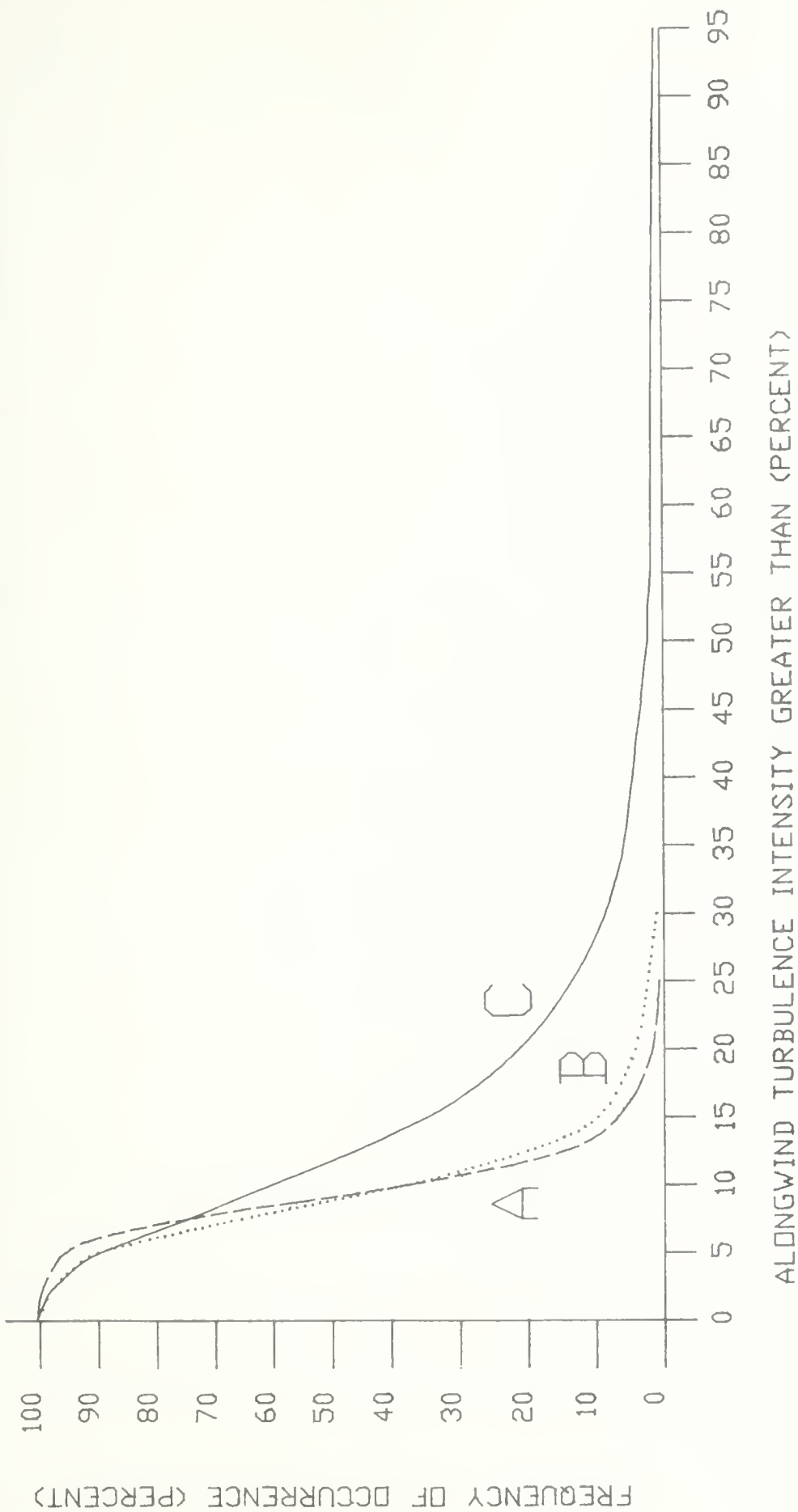
FIGURE 3-7

PERCENT FREQUENCY OF ALONGWIND TURBULENCE INTENSITIES (30 METERS)
ABOVE INDICATED VALUES FOR WIND SPEED OF:
A) 12-14 M/S   B) 6-8 M/S   C) 2-4 M/S

A-7DVS0114
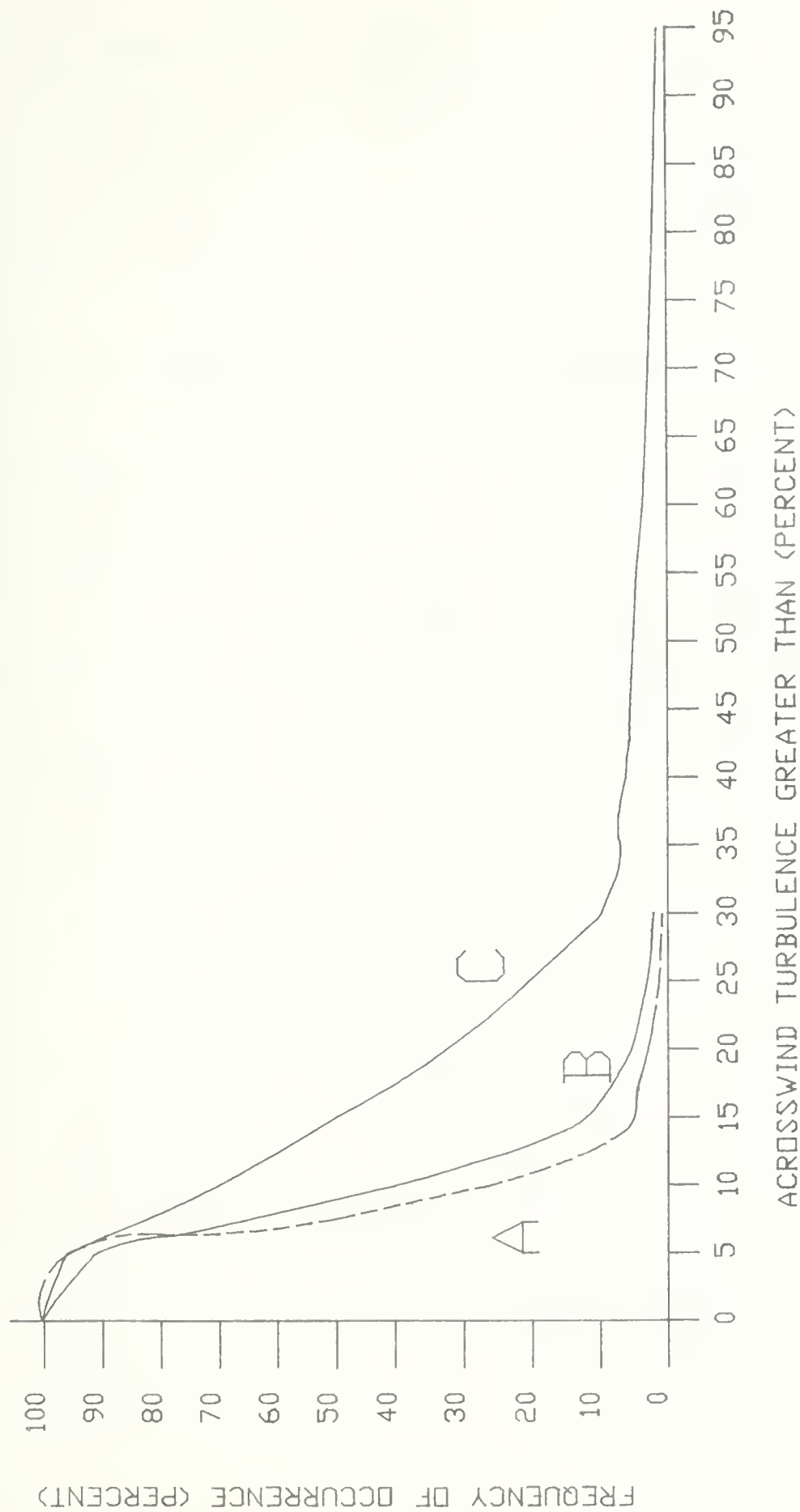
FIGURE 3-8

PERCENT FREQUENCY OF ACROSSWIND TURBULENCE INTENSITIES (30 METERS)
ABOVE INDICATED VALUES FOR WIND SPEED OF:
A) 12-14 M/S   B) 6-8 M/S   C) 2-4 M/S

A-7DW50715

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ACT show a decrease with height for given wind speed categories; this decrease with height becomes more pronounced as wind speed increases. Probably the most important finding is that at power generating wind speeds, turbulence intensities are nearly always in the low or moderate range.

3.2.4 <u>Variation of Turbulence with Wind Direction</u>

Turbulence intensity was found to vary significantly with wind direction. In general, the highest intensities occurred with winds from the northerly and southeasterly directions, and the lowest with southwesterly and easterly winds. Results of this analysis are presented in Table 3-11 and Figure 3-9. One striking feature is that the variation in turbulence with wind direction increases greatly with height. At 9 meters for example, the average ALT ranges from 11-12% for southwesterly and easterly winds, up to 15.3% for north-northeasterly winds. At 46 meters average ALT values range from 9.7% for easterly winds up to 19.4% for south-southeasterly winds.

For southeasterly directions, both ALT and ACT increase greatly with height, which seems to contradict previous findings. However, winds from the southeast tend to be very light, so the high ALT and ACT intensities associated with this direction are not really of concern to developers. Because winds from this direction are light, they often are presumed to be associated with temperature inversion conditions, when airflow in the atmosphere near the

TABLE 3-11. AVERAGE TURBULENCE INTENSITY BY WIND DIRECTION CATEGORY
AT LIVINGSTON, MONTANA
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

Average Turbulence Intensity

Wind Direction	Alongwind 9 Meters	Acrosswind 9 Meters	Alongwind 30 Meters	Acrosswind 30 Meters	Alongwind 46 Meters	Acrosswind 46 Meters
N	14.3	18.8	14.7	18.4	14.2	18.5
NNE	14.5	22.5	14.3	20.7	13.6	22.0
NE	13.3	18.5	12.5	17.4	12.3	18.6
ENE	11.1	13.1	10.2	12.3	9.7	11.8
E	11.5	11.4	11.1	10.7	11.5	9.9
ESE	12.0	15.2	12.5	15.6	14.5	16.2
SE	11.6	16.6	15.5	23.1	17.6	26.8
SSE	12.8	19.4	16.6	23.9	19.4	28.2
S	12.0	13.0	10.5	10.5	10.8	11.5
SSW	11.7	11.4	10.5	11.1	9.9	10.5
SW	11.5	13.0	10.2	12.4	10.1	12.5
WSW	11.1	12.5	9.8	11.4	9.2	11.1
W	13.3	15.5	11.4	13.6	10.7	13.3
WNW	15.1	20.0	14.2	19.1	13.2	19.1
NW	15.3	22.4	15.7	22.3	15.2	23.0
NNW	15.3	20.7	14.3	17.7	14.3	19.1
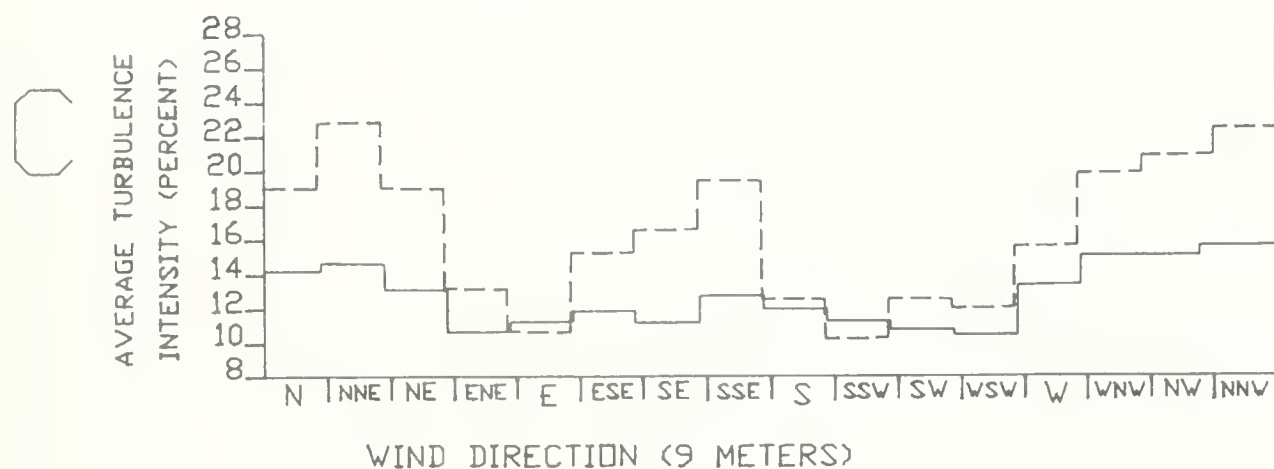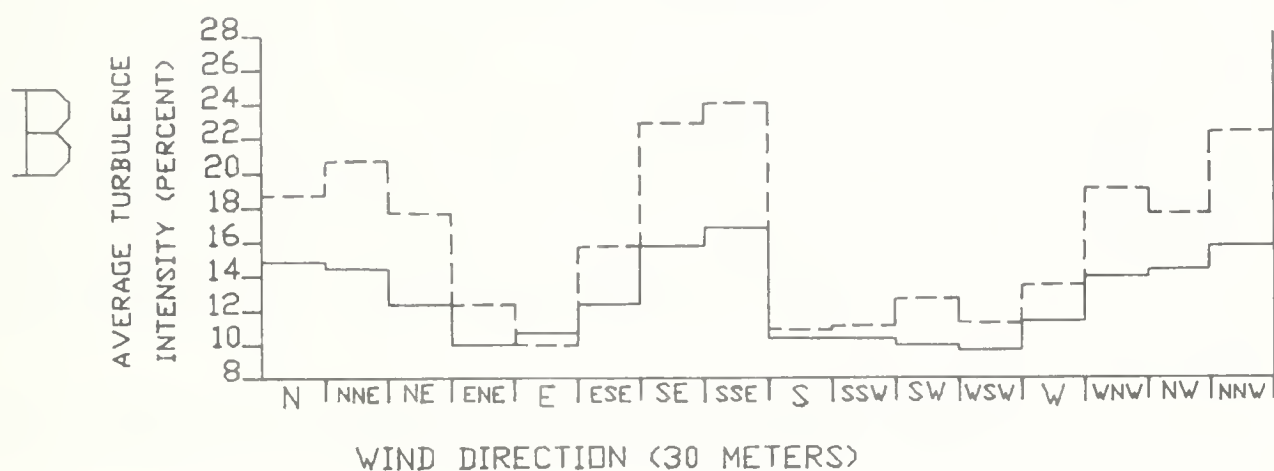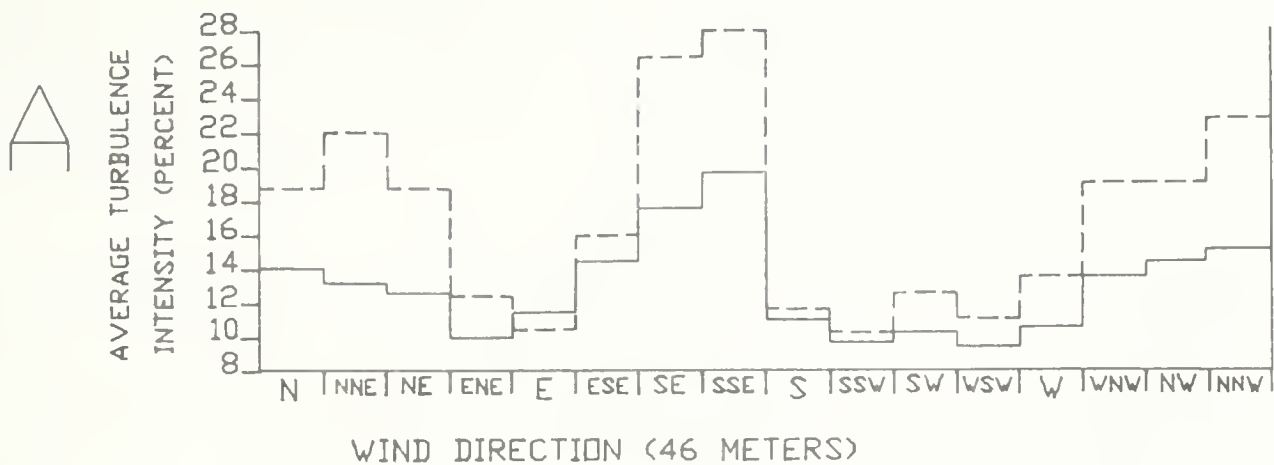
FIGURE 3-9

AVERAGE TURBULENCE INTENSITY BY WIND DIRECTION
CATEGORY AT LIVINGSTON, MONTANA
_____ = ALONGWIND   ------- = ACROSSWIND
A) 46 METERS   B) 30 METERS   C) 9 METERS

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A-7DW50111

ground is dominated by surface terrain features. This results in less consistent airflow with height above ground, as the channeling effects of the surface terrain weaken. This mechanism is suspected as the cause of the increase in ALT and ACT with height during southeasterly winds.

It is probably no coincidence that the wind directions associated with the highest turbulence intensities tend to have the lowest wind speeds and vice versa. The association of wind direction with turbulence intensity, while well-defined, is probably indirect. That is, turbulence intensity is very strongly correlated with wind speed, which in turn is strongly correlated with wind direction. The higher turbulence levels associated with winds from the northerly and southeasterly directions are of little concern, because these winds are almost invariably light.

3.2.5 Variation of Turbulence with Atmospheric Stability

Several methods have been used to define atmospheric stability. A system developed by Pasquill considers cloud cover, sun angle, and wind speed to classify stability by seven categories ranging from very unstable (Category A) to very stable (Category G). At Livingston, a scheme developed by the Atomic Energy Commission was more practical; it estimates the Pasquill stability category from the change in temperature with height.

Turbulence varies considerably with atmospheric stability, as shown in Table 3-12. The highest ALT and ACT levels occurred during very unstable and very stable conditions. In Pasquill's scheme, these categories are associated with very light winds, so this finding is consistent. Average turbulence intensities did not vary greatly through the other stability categories, which are usually associated with higher wind speeds.

At 9 meters, the highest ALT levels occurred during Category A conditions but at 46 meters they occurred during Category G conditions. This probably is because during Category A conditions intense solar heating is occurring, causing high turbulence at the ground that decrease with height. During Category G conditions, a strong temperature inversion is present. As discussed in Section 3.2.4, this often results in more consistent airflow near the ground because of surface terrain effects. Another feature is that ACT is significantly greater than ALT during Category A and Category G conditions, but they are nearly equal during Category D and E conditions. Again, this probably relates to the low wind speeds observed during A and G conditions, and the higher wind speeds during D and E conditions. ACT is considerably higher than ALT during low wind speeds, but somewhat lower during high wind speeds.

It is not clear whether atmospheric stability has its own effect on turbulence intensity, or whether these effects merely reflect variations in wind speed and wind direction consistency through the

TABLE 3-12. AVERAGE TURBULENCE INTENSITY BY DELTA T
(TEMPERATURE @ 46M MINUS TEMPERATURE @ 9M)
AT LIVINGSTON, MONTANA
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

Delta T (Pasquill Stability Category)	Average Turbulence Intensity					
	Alongwind 9 Meters	Acrosswind 9 Meters	Alongwind 30 Meters	Acrosswind 30 Meters	Alongwind 46 Meters	Acrosswind 46 Meters
<-0.8 (A-B)	15.0	18.8	13.3	16.9	12.5	16.4
-0.8 to -0.6 (C)	12.7	14.3	11.2	12.9	10.6	12.3
-0.6 to -0.2 (D)	12.3	13.3	11.2	12.5	11.0	12.2
-0.2 to +0.5 (E)	11.3	12.3	10.4	11.8	10.2	11.6
+0.5 to +1.4 (F)	10.6	13.9	10.7	13.9	10.5	14.0
>+1.4 (G)	13.5	20.0	13.5	18.2	13.4	18.6

stability categories. However, the variation of turbulence intensity with atmospheric stability appears to be well defined, based on this analysis.

3.2.6 Variation of Turbulence with Thunderstorms

At the beginning of this study, concerns were expressed that the strong, gusty winds often associated with thunderstorms could be of concern to wind developers. At the Livingston airport, located only two miles from the wind shear and turbulence study site, weather observations are performed and recorded by the Federal Aviation Administration (FAA), including notations of thunderstorms and other weather phenomena. Therefore, the Livingston study provided a good opportunity to investigate the impact of thunderstorm conditions on atmospheric turbulence.

Starting times and ending times of thunderstorm events at Livingston were obtained from the FAA records and catalogued. Next, the alongwind and acrosswind turbulence intensity data for the 30-meter level at the study site were recorded for these same data periods at 10-minute intervals. The 30-meter level was selected because it represents a typical hub height for wind machines commonly in use today. Table 3-13 shows a comparison of the turbulence data collected during thunderstorm periods in June, July, and August with all turbulence data for those months.

**TABLE 3-13. SUMMARY OF TURBULENCE INTENSITY DURING
THUNDERSTORM CONDITIONS AT LIVINGSTON, MONTANA**

Percent Frequency of:	0-5	5-10	10-15	15-20	20-25	25-30	30<	Avg.
ALT 30 meters during thunderstorms	5.6	41.6	33.1	8.4	6.2	1.1	3.9	12.6%
ALT 30 meters overall	8.2	44.2	27.3	10.1	4.3	1.8	3.5	13.1%
ACT 30 meters during thunderstorms	2.8	32.0	36.0	12.9	6.7	3.4	5.1	14.2%
ACT 30 meters overall	4.3	35.7	25.5	21.5	7.2	4.2	11.3	17.0%

This analysis indicates that during thunderstorm episodes, ALT tends to remain about the same as during other periods and that ACT decreases significantly. This is actually consistent with the earlier analyses, because thunderstorms are not generally accompanied by either light winds or stable atmospheric stability, conditions which were shown to contribute to increases in turbulence intensity. While strong gusty winds often do accompany thunderstorms, they seldom attain the duration or intensity of those occurring during the winter months at Livingston. In fact, all three sets of anemometer cups stayed on throughout the thunderstorm season.

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3.3 WIND SHEAR

Wind shear data were collected every two minutes during this study, between heights of 9 meters and 30 meters, 9 meters and 46 meters, and 30 meters and 46 meters. These data were calculated both in terms of absolute ms^{-1} differences in wind speed and in terms of the power law exponent (P) discussed in Chapter 1.0. The following sections present and discuss the summarized wind shear characteristics at Livingston. Next, wind shear characteristics are related to time of day, wind speed, wind direction, atmospheric stability, and turbulence intensity. A comparison of the average 2-minute wind shears with the maximum instantaneous wind shears during these same periods also is presented.

3.3.1 General Wind Shear Characteristics

The wind shear at Livingston appears to be comparable to that observed at other wind energy study sites, based on the power law exponent. The average P-value (PWS) ranged from 0.078 between 9 and 30 meters to 0.098 between 30 and 46 meters; a value of 0.100 is considered typical for windy sites. The absolute wind shear (AWS) averages were 0.84 ms^{-1} between 9 and 30 meters, and 0.42 ms^{-1} between 30 and 46 meters.

Average monthly wind shear data are presented in Table 3-14. For both P-values and absolute wind shears, the highest values occurred during the winter and the lowest values during the summer. The

TABLE 3-14. MONTHLY AVERAGE WIND SHEAR AT LIVINGSTON, MONTANA
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

Month*	Average Shear Between 9-30 Meters		Average Shear Between 9-46 Meters		Average Shear Between 30-46 Meters	
	(m/s)	(P)	(m/s)	(P)	(m/s)	(P)
March	1.17	0.096	1.54	0.099	0.36	0.092
April	0.75	0.082	1.00	0.086	0.23	0.085
May	0.71	0.067	1.02	0.074	0.25	0.095
June	0.63	0.076	0.82	0.078	0.19	0.083
July	0.66	0.076	0.87	0.077	0.22	0.085
August	0.51	0.065	0.67	0.068	0.17	0.084
September	0.72	0.076	0.90	0.074	0.19	0.081
October	0.77	0.075	1.21	0.082	0.32	0.108
November	0.95	0.075	1.36	0.079	0.40	0.094
December	1.46	0.103	2.11	0.106	0.67	0.124

*Because of equipment malfunctions, no wind shear data were collected
 during the months of January or February.

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largest variations were observed for AWS between 9 and 46 meters (AWS 9-46), which ranged from 0.82 ms^{-1} in June up to 2.11 ms^{-1} in December. The range in PWS between the same levels (PWS 9-46) ranged from 0.068 in August up to 0.106 in December. The AWS showed a large decrease with height; approximately 70% of the total AWS between 9 and 46 meters generally occurred between 9 and 30 meters. By contrast, PWS tended to increase with height; the average annual value between 30 and 46 meters was 0.093, versus only 0.078 between 9 and 30 meters. Only two months, October and December, had average PWS values exceeding 0.100, the highest being 0.124 between 30 and 46 meters. In no cases can the mean monthly PWS values be considered significantly above average.

Frequency distributions of AWS and PWS are presented in Table 3-15 and in Figures 3-10 and 3-11. AWS values between 0 and 2 ms^{-1} were quite common at all levels, with peaks occurring between 0 and 1 ms^{-1}. As would be expected, the higher ranges were most common between 9 and 46 meters. Shears between 3 and 4 ms^{-1} occurred nearly 5% of the time between 9 and 46 meters, but less than 1% of the time between the other levels. Since velocity tends to increase logarithmically with height, one would expect AWS values between 30 and 46 meters to be the lowest.

PWS values were usually between 0 and 0.200 for all levels, but more scatter in the data occurred for PWS between 30 and 46 meters. Negative PWS values, indicating a decrease in wind speed with height, occurred 14.6% of the time between 9 and 46 meters, and

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TABLE 3-15. FREQUENCY DISTRIBUTION OF WIND SHEAR AT LIVINGSTON, MONTANA
DATA PERIOD SEPTEMBER 1985 – NOVEMBER 1986

Power Law Exponent (P) >	Power Law Exponent (P) <	Percent Frequency Shear Between 9m-30m	Percent Frequency Shear Between 9m-46m	Percent Frequency Shear Between 30m-46m	Wind Shear (m/s)	Percent Frequency Shear Between 9m-30m	Percent Frequency Shear Between 9m-46m	Percent Frequency Shear Between 30m-46m
	-0.2	2.11	1.38	3.93	<0	14.58	12.99	21.10
-0.2	-0.1	3.25	2.27	3.61	0-1	48.88	39.27	72.52
-0.1	0	9.22	9.35	13.56	1-2	29.50	28.98	6.10
0	0.1	44.97	49.29	36.71	2-3	6.44	12.89	0.24
0.1	0.2	33.61	30.93	26.02	3-4	0.58	4.64	0.04
0.2	0.3	4.97	4.84	8.52	4-5	0.02	1.07	*
0.3	0.4	1.12	1.26	3.12	5-6	*	0.14	*
0.4	0.5	0.43	0.45	1.53	6-7	*	0.02	0
0.5	0.6	0.19	0.16	0.95	7-8	0	*	0
0.6	0.7	0.08	0.05	0.63				
0.7	0.8	0.04	0.02	0.43				
0.8	0.9	0.01	0.01	0.29				
0.9	1.0	*	*	0.20				
1.0	1.1	*	*	0.14				
1.1	1.2	*	*	0.08				
1.2	1.3	*	*	0.06				
1.3	1.4	*	*	0.04				
1.4	1.5	*	*	0.03				
1.5	1.6	*	*	0.02				
1.6		*	*	0.13				

*Denotes occurrences less than 0.005% of the time.
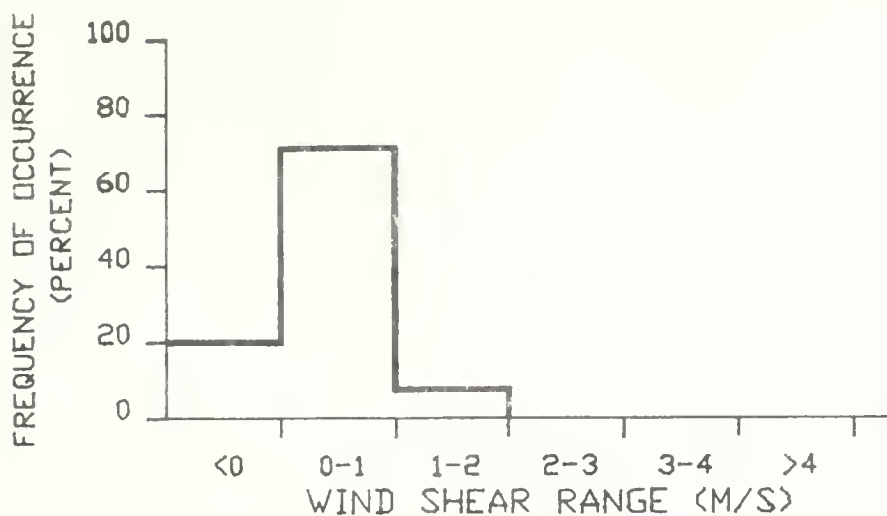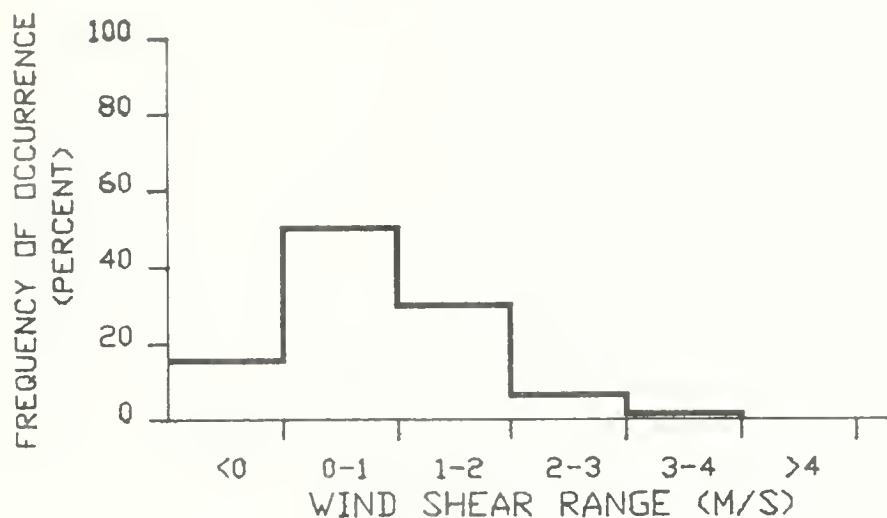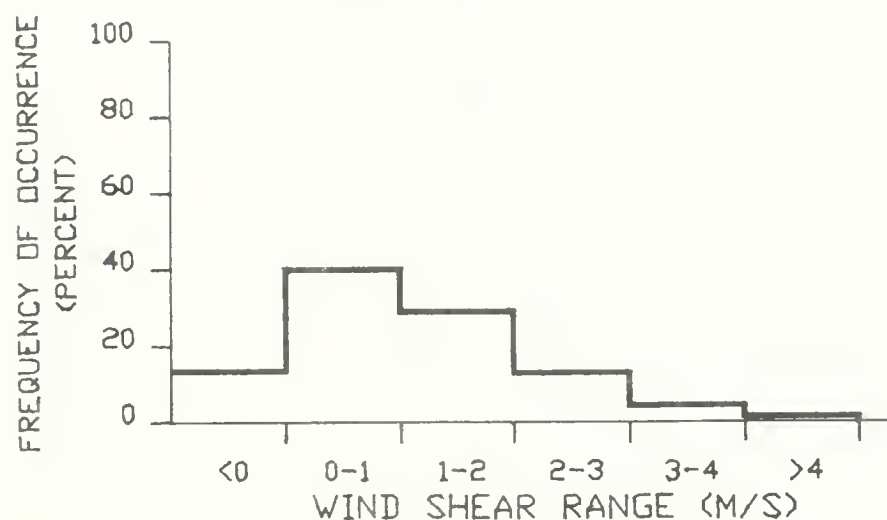
FIGURE 3-10

FREQUENCY DISTRIBUTION OF ABSOLUTE WIND
SHEAR (M/S) AT LIVINGSTON, MONTANA FOR:

A) 30-46 METERS   B) 9-30 METERS   C) 9-46 METERS

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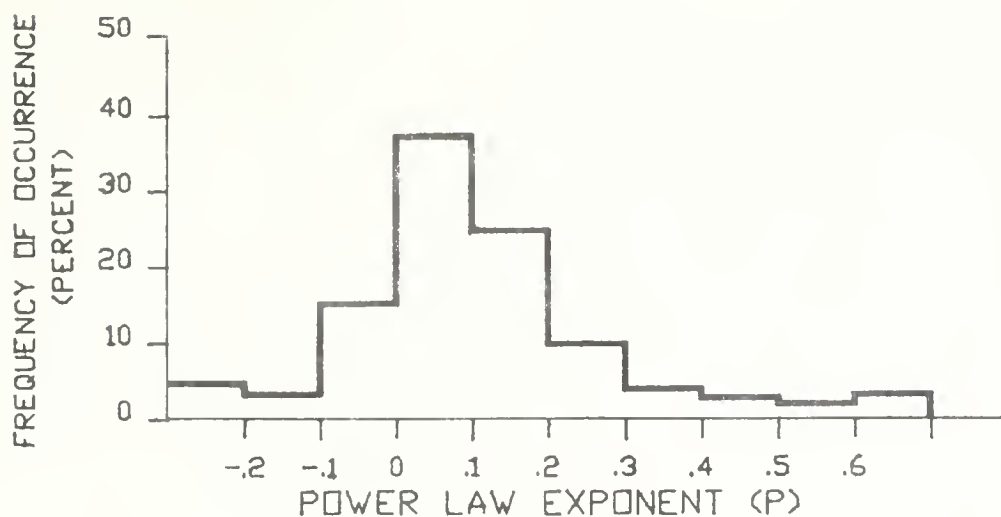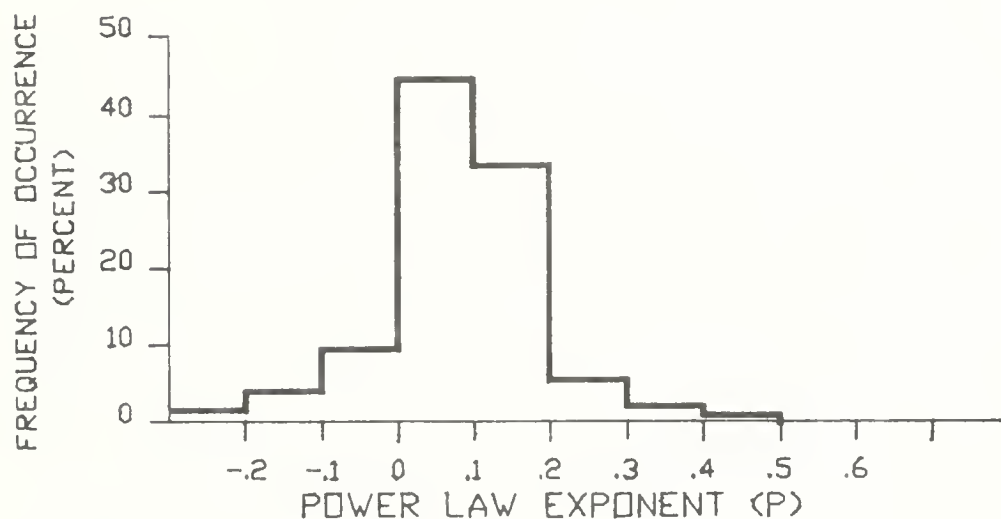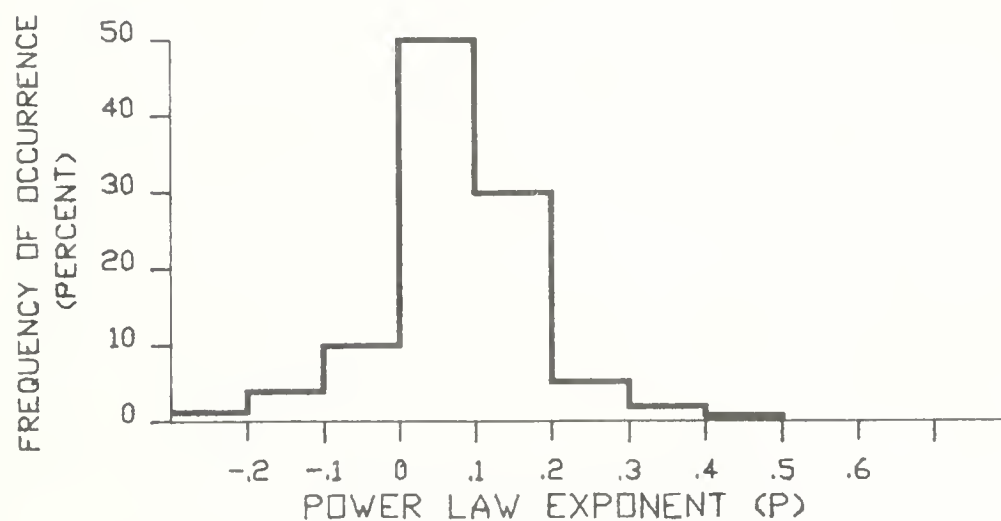
FIGURE 3-11

FREQUENCY DISTRIBUTION OF WIND SHEAR (P)
AT LIVINGSTON, MONTANA FOR:

A) 30-46 METERS   B) 9-30 METERS   C) 9-46 METERS

DATA PERIOD SEP. 1985 - NOV. 1986   A-7DW50103

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over 20% of the time between 30 and 46 meters. Values above 0.200 and values below 0 occurred with nearly equal frequencies. Figures 3-12 and 3-13 show the frequency of occurrence of AWS and PWS above specified levels. Well under half of the PWS values exceed 0.100 and less than one-fifth exceed 0.200 at all levels. AWS values above 2 ms^{-1} occurred over 7% of the time between 9 and 30 meters, but less than 1% of the time between 30 and 46 meters. This reinforces earlier indications that most of the AWS occurs below 30 meters.

In Table 3-16 occurrence frequencies of AWS for different categories are presented by month. These follow a pattern similar to that shown by the monthly averages. During the months with higher average shears, shears in the higher ranges become much more common. This is particularly noticeable for December, when the AWS 9-46 meters exceeded 3 ms^{-1} 23% of the time, versus less than 1% in August. Different ranges were used for AWS 30-46, because of the generally lower values as compared to shears between other tower levels. On a month-by-month basis, the frequency of AWS 9-46 above 3 ms^{-1} is almost identical to the frequency of AWS 30-46 meters above 1 ms^{-1}.

In conclusion, the wind shear at Livingston appears to be comparable to that at other windy sites, based on PWS values. Both PWS and AWS tend to be lowest during the summer months, and highest in the winter. A slight increase in PWS with height also was noticed. Over 70% of the observed AWS, by contrast, occurred
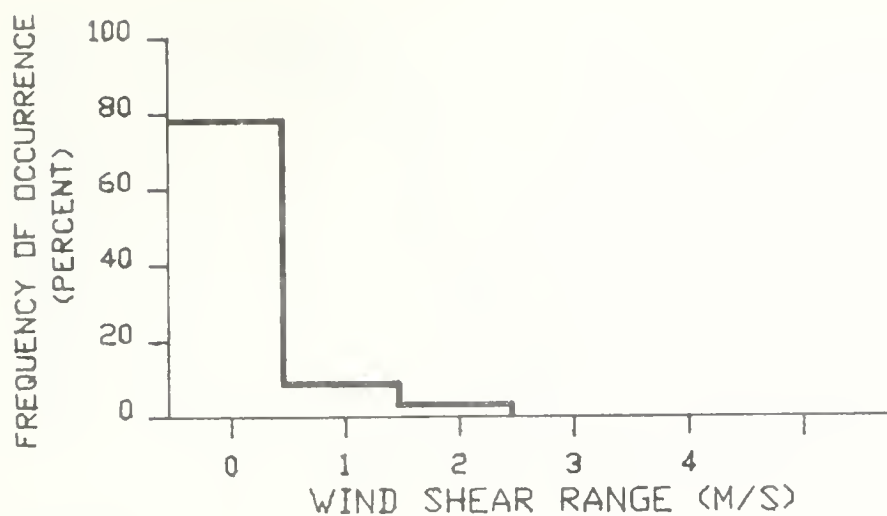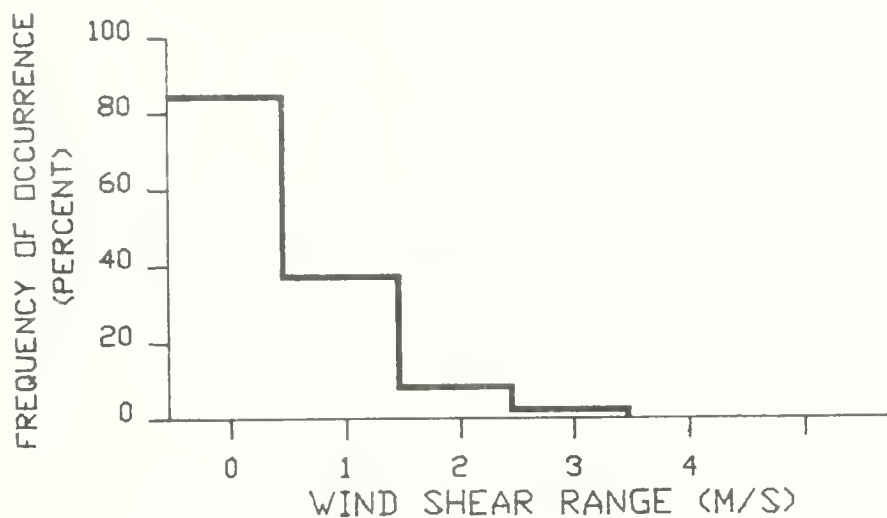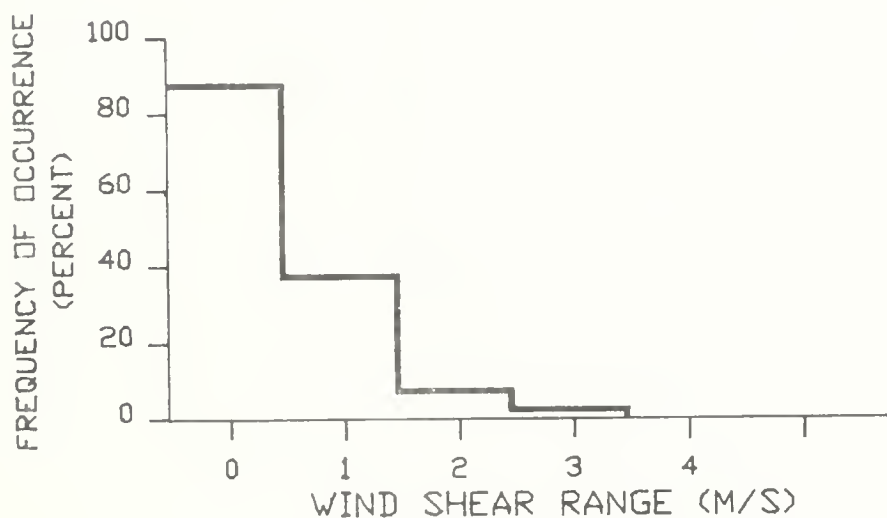
FIGURE 3-12

CUMULATIVE FREQUENCY DISTRIBUTION OF ABSOLUTE WIND
SHEAR (M/S) AT LIVINGSTON, MONTANA FOR:

A) 30-46 METERS   B) 9-30 METERS   C) 9-46 METERS

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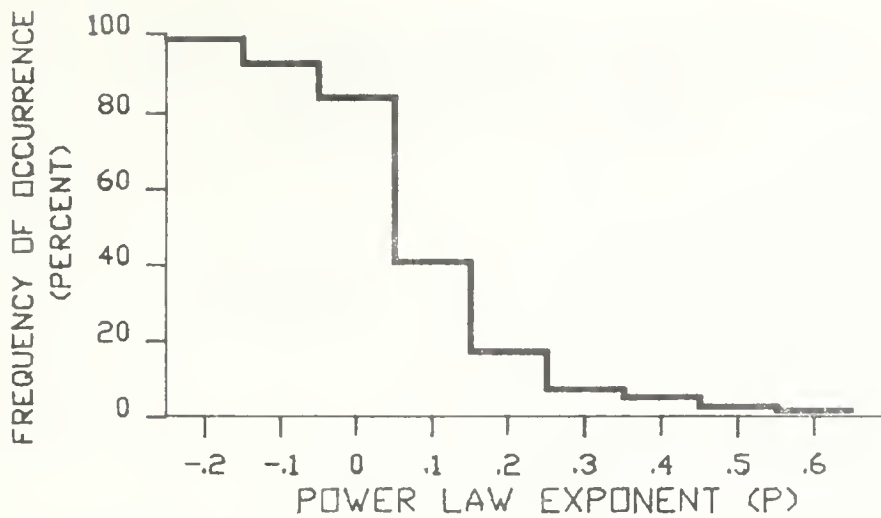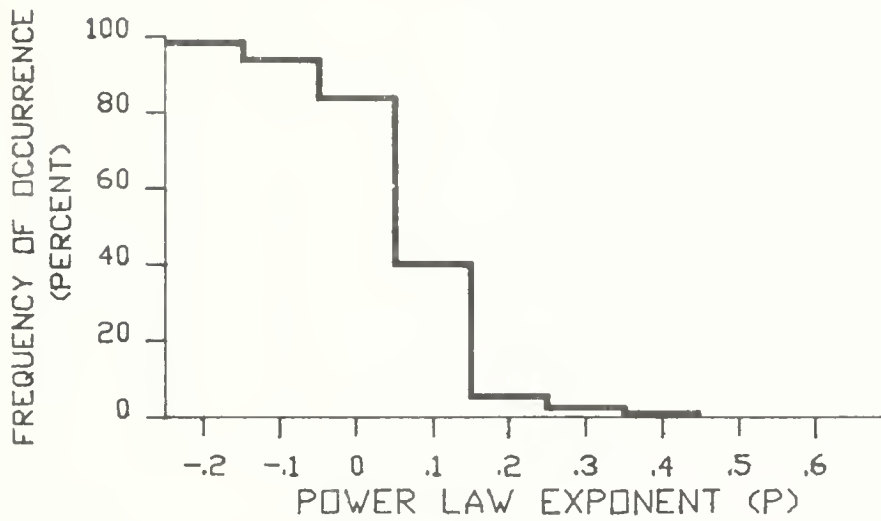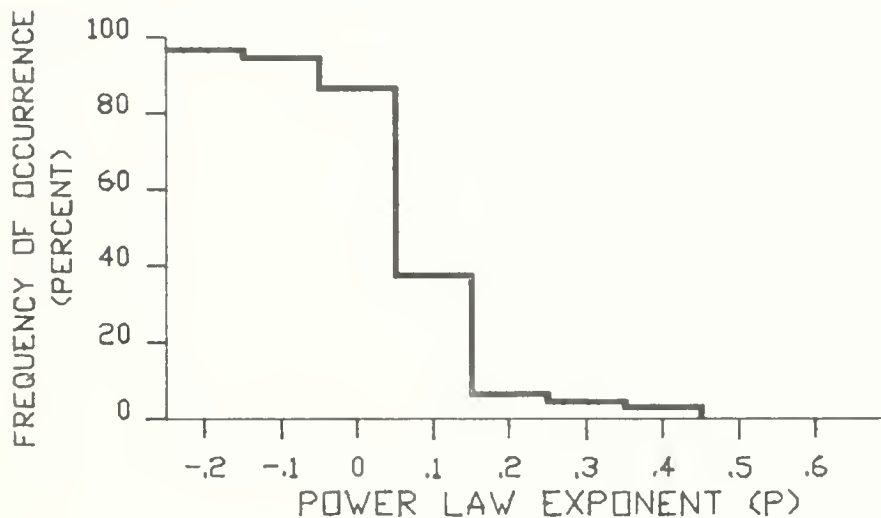
FIGURE 3-13

CUMULATIVE FREQUENCY DISTRIBUTION OF WIND SHEAR (P)
AT LIVINGSTON, MONTANA FOR:

A) 30-46 METERS   B)9-30 METERS   C) 9-46 METERS

DATA PERIOD SEP. 1985 - NOV. 1986   A-7DW50104

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TABLE 3-16. FREQUENCY OF OCCURRENCE OF ABSOLUTE WIND SHEAR RANGES
AT LIVINGSTON, MONTANA BY MONTH
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

Month*	Shear Between 9 and 30 Meters (m/s)			Shear Between 9 and 46 Meters (m/s)			Shear Between 30 and 46 Meters (m/s)		
	<1	1-3	>3	<1	1-3	>3	<0	0-1	>1
March	40.2	59.4	0.4	27.9	57.1	5.0	13.0	83.5	3.5
April	65.1	34.6	0.3	53.1	44.4	2.5	22.1	75.2	2.7
May	65.2	34.6	0.2	54.9	40.0	5.1	22.4	73.3	4.3
June	74.4	25.3	0.3	65.1	32.9	2.0	26.6	70.6	2.9
July	70.8	29.1	0.1	61.5	35.9	2.6	25.1	72.1	2.7
August	77.6	22.4	<0.1	70.4	28.2	1.4	31.3	65.9	2.8
September	67.4	32.6	<0.1	59.6	39.6	0.8	23.8	74.3	2.0
October	64.2	35.4	0.4	47.6	45.1	7.3	20.0	73.1	6.9
November	50.9	37.5	1.6	49.4	41.9	8.7	16.9	73.0	10.1
December	27.5	69.9	2.7	16.9	60.1	23.0	7.1	68.2	24.7

*Because of equipment malfunctions. no wind shear data were
collected during the months of January or February.

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between the 9 and 30 meter levels; between 30 and 46 meters AWS values above 1 ms^{-1} were generally infrequent. In general PWS and AWS appear to have a positive correlation. The months with the highest wind shear values also tended to have the lowest turbulence levels.

3.3.2 <u>Variations in Wind Shear with Time of Day</u>

Both AWS and PWS show a strong relationship with time of day. Table 3-17 and Figure 3-14 show average values for each hour of the day, based on the entire data set. Nearly identical patterns were observed for both AWS and PWS; the highest values occurred around dawn and particularly at dusk, and the lowest values around mid-day. A slight secondary minimum was observed around midnight. Variations in AWS 30-46 were fairly minimal compared to AWS 9-30 and AWS 9-46. As with turbulence, the diurnal variations in wind shear are probably related to the nocturnal temperature inversion cycle.

Because of radiational cooling on clear nights, the Livingston area is expected to experience a high frequency of nighttime temperature inversions. During these periods, airflow at the surface becomes uncoupled from the airflow aloft and is dominated by local terrain features rather than the large-scale airflow. Winds near the surface also become very light during these periods, as they are not enhanced by the stronger winds aloft. This results in less wind shear near the ground, and more shear aloft (e.g., above 9

Hour of the Day	Average Shear From 9-30 Meters (m/s)	(P)	Average Shear From 9-46 Meters (m/s)	(P)	Average Shear From 30-46 Meters (m/s)	(P)
01	0.84	0.087	1.15	0.090	0.44	0.125
02	0.85	0.085	1.20	0.089	0.46	0.131
03	0.84	0.082	1.19	0.089	0.45	0.135
04	0.87	0.084	1.23	0.091	0.45	0.142
05	0.90	0.084	1.26	0.089	0.45	0.124
06	0.90	0.086	1.30	0.089	0.47	0.125
07	0.89	0.082	1.24	0.087	0.47	0.123
08	0.81	0.067	1.13	0.075	0.43	0.113
09	0.74	0.059	1.04	0.066	0.40	0.087
10	0.70	0.054	0.95	0.058	0.37	0.070
11	0.71	0.054	0.96	0.055	0.38	0.057
12	0.73	0.056	0.96	0.056	0.37	0.054
13	0.74	0.058	0.97	0.053	0.36	0.047
14	0.77	0.059	1.01	0.056	0.37	0.052
15	0.77	0.065	0.99	0.061	0.37	0.054
16	0.80	0.067	1.05	0.064	0.38	0.057
17	0.86	0.077	1.15	0.074	0.41	0.069
18	0.91	0.093	1.22	0.089	0.43	0.084
19	0.96	0.097	1.30	0.093	0.43	0.095
20	1.00	0.104	1.33	0.099	0.42	0.104
21	0.98	0.104	1.34	0.099	0.45	0.112
22	0.89	0.099	1.25	0.101	0.46	0.132
23	0.85	0.088	1.16	0.092	0.45	0.131
24	0.84	0.086	1.09	0.093	0.41	0.133
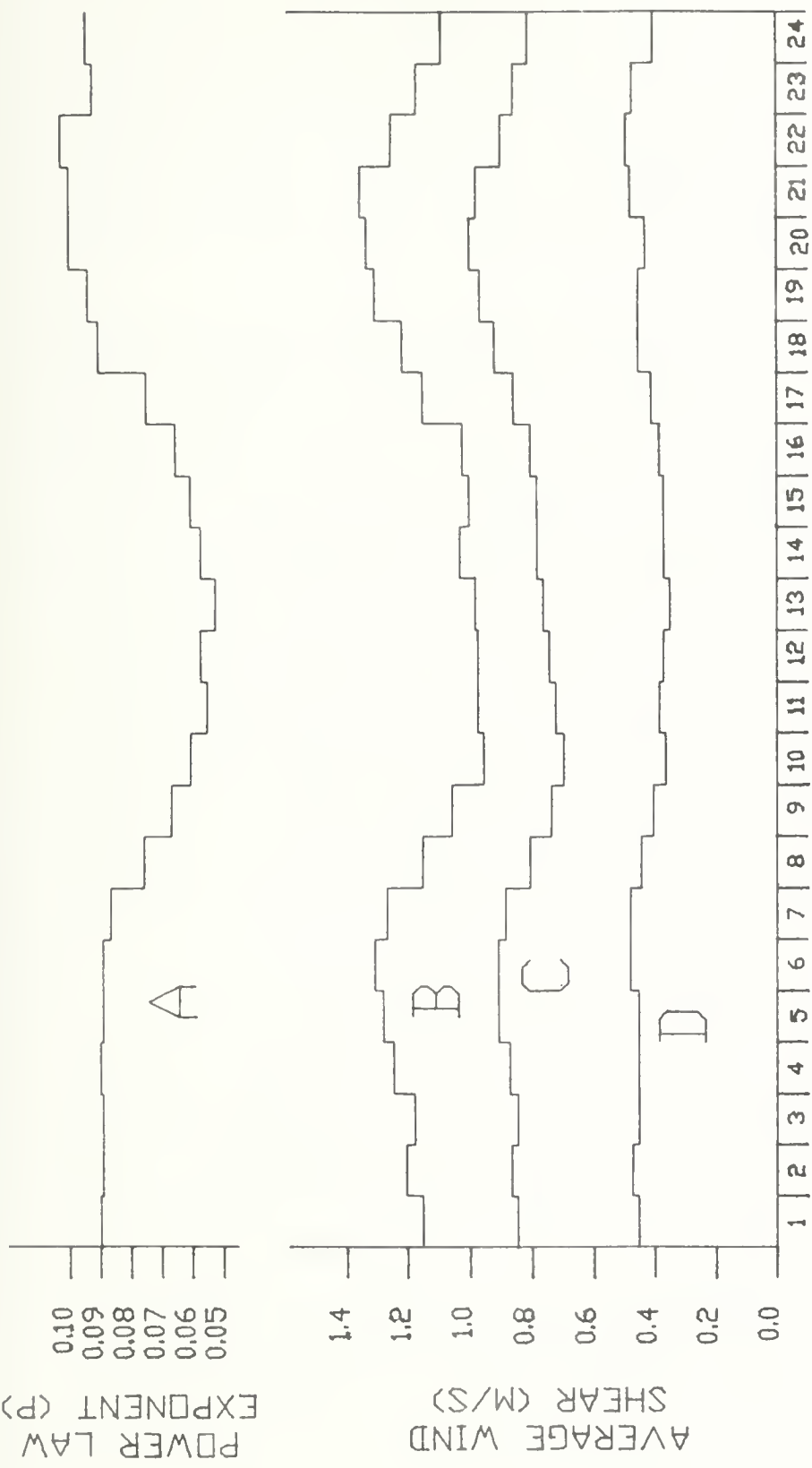
AVERAGE WIND SHEAR BY TIME OF DAY AT LIVINGSTON, MONTANA
A) PWS FROM 9-46 METERS   B) AWS FROM 46-9 METERS
C) AWS FROM 30-9 METERS   D) AWS FROM 46-30 METERS

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FIGURE 3-14

A-7DWS0117

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meters). In contrast, during the daytime the large-scale airflow is present even at ground level. This results in greater frictional effects at ground level; i.e., most of the increase in wind speed takes place very near the ground (e.g., below 9 meters). These inversion phenomena are suspected to be responsible in large part for the diurnal variations in wind shear.

Similarly, the sharp peak observed around dusk for AWS 9-30 and AWS 9-46 probably results from the tendency for nocturnal temperature inversions to form at that time. Inversions generally form at the surface, and gradually deepen with time. The sharp peak in wind shear at dusk is probably associated with periods when the temperature inversion is present at 9 meters, but has not yet deepened to encompass the 30 meter or 46 meter levels. These periods would have very light winds at 9 meters, and much stronger winds at 30 and 46 meters. Later in the evening, as the inversion deepens, these sharp variations in wind speed would tend to subside, but still remain greater than during the daytime.

In terms of PWS 9-46 on an annual basis, all hours show values that can be considered low to moderate. Values below 0.060 were observed for several hours around mid-day, and the highest average value, observed at 2200, was only 0.101. Also it is evident that wind shear behaves in a nearly opposite manner from turbulence intensity. Periods of the day with the higher turbulence intensities tended to have the lower wind shears, and vice versa.

3.3.3 Variation of Wind Shear with Wind Speed

As with turbulence intensity, a very strong relationship was observed between wind shear and wind speed. Average wind shears between each of the three tower levels were calculated for each observed 2 ms^{-1} wind speed range at given levels. Average wind shears between 9 and 30 meters were related to the wind speed at 9 meters; average shears between 9 and 46 meters were related to the wind speed at 30 meters; and average shears between 30 and 46 meters were related to the wind speed at 46 meters. The results are presented in Table 3-18 and Figure 3-15. Shears between 9 and 46 meters were related to wind speeds at 30 meters, rather than speeds at 9 or 46 meters (although the speeds at 9 and 46 meters were used to calculate these shears) because 30 meters is near the middle of the layer across which the shears were calculated. The intention was to relate the wind shear across this layer to the approximate average wind speed within this layer.

In terms of AWS, a very consistent increase was observed with increasing wind speed. As indicated by the previous analyses in this report, most of the observed shear occurred between 9 and 30 meters; for any given wind speed category above 4 ms^{-1}, the AWS 30-46 was only slightly over one third of the AWS 9-30. In fact, AWS appears to be a nearly linear function of wind speed. A linear regression of average AWS values against the midpoints of the corresponding wind speed ranges was performed to quantify this correlation, using only wind speeds above 6 ms^{-1} (a typical wind

Wind Speed (m/s)	Average Shear From 9-30 Meters[1]		Average Shear From 9-46 Meters[2]		Average Shear From 30-46 Meters[3]	
	(m/s)	(P)	(m/s)	(P)	(m/s)	(P)
0-2	0.10	0.013	0.11	0.016	0.30	0.078
2-4	0.35	0.045	0.43	0.061	0.28	0.135
4-6	0.73	0.101	0.80	0.098	0.33	0.093
6-8	0.92	0.010	1.08	0.099	0.37	0.079
8-10	1.10	0.094	1.32	0.093	0.42	0.082
10-12	1.34	0.093	1.62	0.092	0.47	0.084
12-14	1.58	0.092	1.98	0.095	0.54	0.092
14-16	1.79	0.090	2.42	0.102	0.67	0.110
16-18	2.03	0.091	2.72	0.101	0.81	0.117
18-20	2.30	0.093	3.02	0.101	0.89	0.115
20-22	2.60	0.094	3.35	0.104	0.99	0.114
22-24	2.81	0.090	3.69	0.107	1.12	0.116
24-26	2.96	0.082	3.93	0.101	1.17	0.112
26-28	3.33	0.092	4.24	0.110	1.20	0.104
28-30	3.50	0.050	4.77	0.115	1.41	0.121
30-32			5.28	0.117	1.68	0.138
32-34					1.64	0.150
34-36						

1. By wind speed at 9 meters.

2. By wind speed at 30 meters.

3. By wind speed at 46 meters.
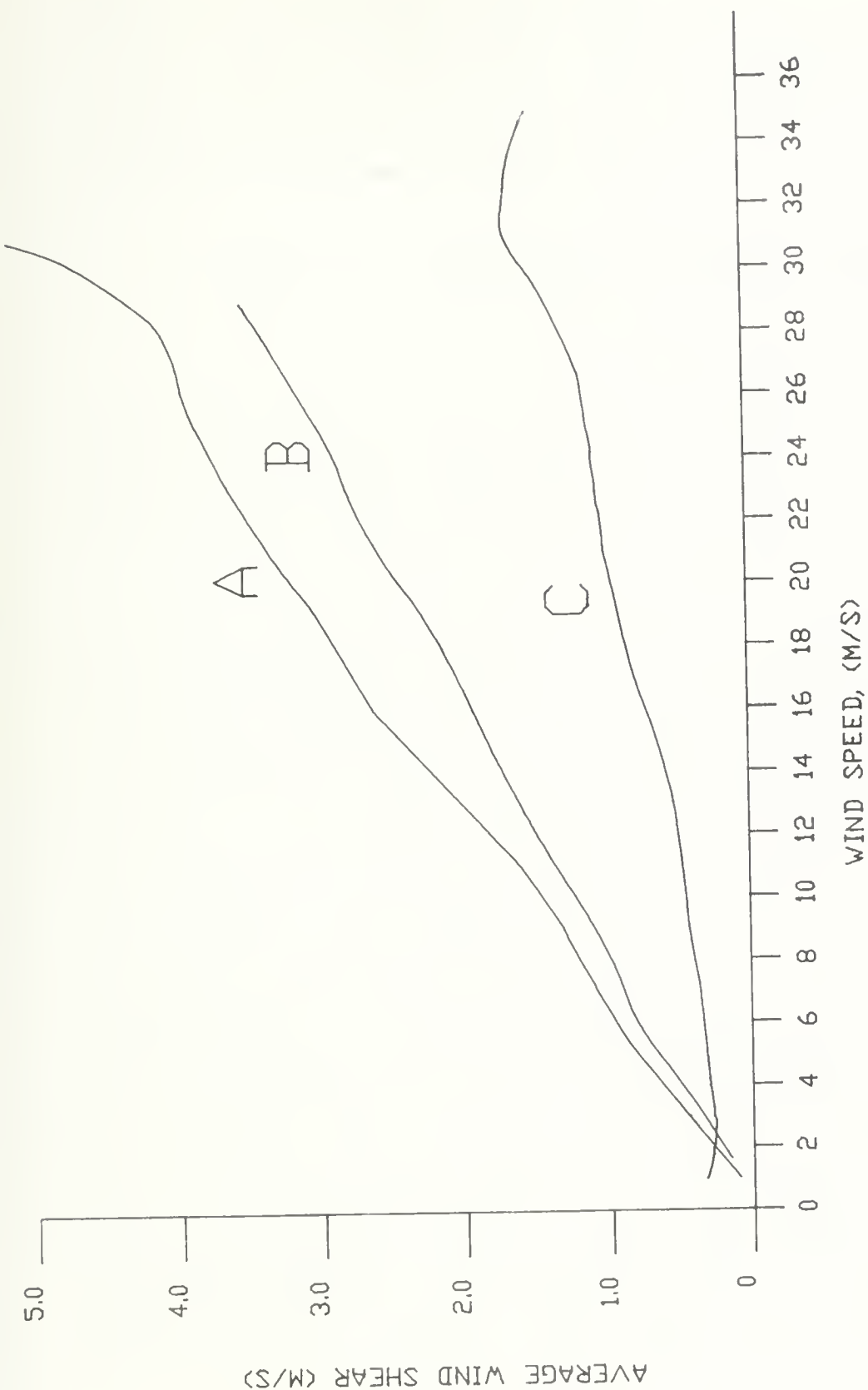
WIND SPEED, (M/S)

AVERAGE WIND SHEAR VERSUS WIND SPEED AT LIVINGSTON, MONTANA
A) WIND SHEAR FROM 46-9 METERS VS 30 METER WIND SPEED
B) WIND SHEAR FROM 30-9 METERS VS 9 METER WIND SPEED
C) WIND SHEAR FROM 46-30 METERS VS 46 METER WIND SPEED

DATA PERIOD SEP. 1985 - NOV. 1986

AVERAGE WIND SHEAR (M/S)

A-7DW50116

FIGURE 3-15

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generator cut-in speed). The highest observed wind speed category at each level was excluded from this analysis, because each occurred so unfrequently as to lack statistical significance. The results are presented in Table 3-19.

TABLE 3-19.   REGRESSION OF AWS AGAINST WIND SPEED

	Slope	Y-Intercept	R_2
AWS 9-30 versus speed @ 9 meters	0.120	0.03	0.9973
AWS 9-46 versus speed @ 30 meters	0.166	-0.13	0.9973
AWS 30-46 versus speed @ 46 meters	0.051	-0.07	0.9730

The correlations are extremely high at all tower levels, showing that on the average, wind speed is an excellent predictor of AWS. The strong positive correlation of wind speed and AWS should be of concern to developers, because it indicates that worst case conditions for both of these parameters tend to occur simultaneously. For example, at wind speeds between 28 and 30 ms^{-1} the average wind shear between 9 and 46 meters was 4.77 ms^{-1}. This combination could produce a very severe operating environment, with very high differential stresses between the upper and lower part of a wind machine rotor. This is the opposite of what was observed for turbulence, as the highest turbulence values usually occurred with the lower wind speeds. Also, high shears can persist for significant durations. For example, AWS 9-46 values above 4 ms^{-1} persisted for as long as 1 hour, and values above 5 ms^{-1} for as

long as 34 minutes during this study, based on the number of consecutive 2-minute average readings above these values.

Average PWS values for wind speed ranges show a much different behavior. At speeds above 6 ms^{-1}, PWS 9-30 values remained nearly constant, around 0.090, while PWS 30-46 values showed a slight increasing trend. As was noted in previous analyses, PWS 30-46 values were slightly higher than PWS 9-30 values, on the average. The higher values observed at the highest wind speed ranges should be regarded cautiously because they are not statistically significant. In general, the PWS values were very close to the typical 0.100 value even at high wind speeds. This indicates that in terms of PWS, the wind shears observed at Livingston are no more severe than those observed at other sites. The point which must be emphasized is that for a given PWS value, higher wind speeds coincide with higher absolute wind shears. A PWS value of 0.100 with a wind speed of 30 ms^{-1} is of much greater concern than a PWS value of 0.200 with a wind speed of 10 ms^{-1}. Therefore, while the increase in wind speed with height at Livingston appears comparable to that observed at other sites under the same wind speed conditions, the real issue is the more frequent occurrence of extremely high wind speeds at Livingston. This indicates a high probability that more extreme AWS conditions also occur at Livingston. In conclusion, the behavior of wind shear with wind speed at Livingston can be summarized as follows:

- At speeds above 6 ms^{-1}, AWS shows a very strong, linear, positive correlation with wind speed.

- At all speeds above 6 ms^{-1}, AWS 9-30 is much greater than AWS 30-46.

- PWS 30-46 (power law exponent between 30 and 46 meters) is usually greater than PWS 9-30 and PWS 9-46, particularly at the higher wind speeds, even though the absolute wind shear between 30 and 46 meters is generally much lower than between the other levels.

- At speeds above 6 ms^{-1}, PWS 9-30 and PWS 9-46 remain nearly constant; PWS 30-46 increases slightly with increasing wind speed.

3.3.4 Variation of Wind Shear with Wind Direction

Average values of AWS and PWS were calculated for each of the 16 wind directions, and are presented in Table 3-20 and Figure 3-16. A very strong relationship exists between wind shear and wind direction. For AWS between all levels, the highest values were observed during southwesterly winds, with a secondary maximum during easterly winds. Low values were present during southeasterly and northeasterly winds.

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TABLE 3-20. AVERAGE WIND SHEAR BY WIND DIRECTION RANGE AT LIVINGSTON, MONTANA
(P) DENOTES POWER LAW EXPONENT
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

Wind Direction	Average Shear From 9-30 Meters[1]		Average Shear From 9-46 Meters[2]		Average Shear From 30-46 Meters[3]	
	(m/s)	(P)	(m/s)	(P)	(m/s)	(P)
N	0.34	0.032	0.47	0.050	0.32	0.099
NNE	0.26	0.022	0.34	0.035	0.29	0.090
NE	0.30	0.019	0.40	0.028	0.26	0.068
ENE	0.62	0.058	0.80	0.056	0.32	0.056
E	0.71	0.071	0.85	0.066	0.28	0.054
ESE	0.55	0.069	0.59	0.050	0.18	0.043
SE	0.29	0.005	0.47	0.044	0.32	0.149
SSE	0.22	0.006	0.39	0.029	0.33	0.159
S	1.24	0.088	2.10	0.101	0.63	0.130
SSW	1.35	0.095	1.67	0.093	0.61	0.110
SW	0.97	0.098	1.26	0.095	0.44	0.106
WSW	0.90	0.102	1.18	0.099	0.43	0.113
W	0.88	0.099	1.08	0.093	0.41	0.111
WNW	0.68	0.091	0.71	0.077	0.35	0.114
NW	0.39	0.064	0.52	0.050	0.33	0.116
NNW	0.53	0.056	0.79	0.068	0.38	0.117

1. By wind direction at 9 meters.

2. By wind direction at 30 meters.

3. By wind direction at 46 meters.
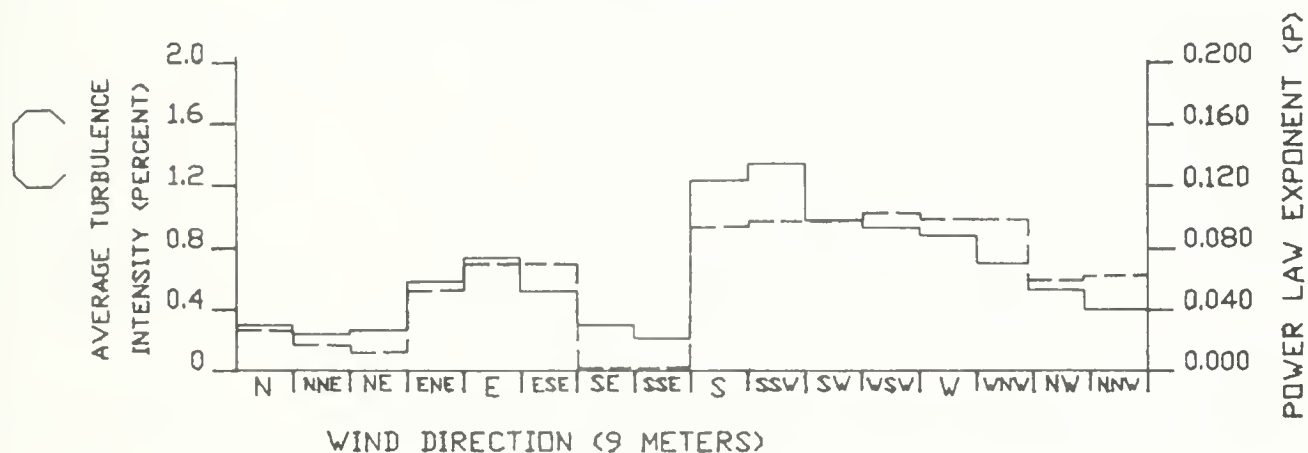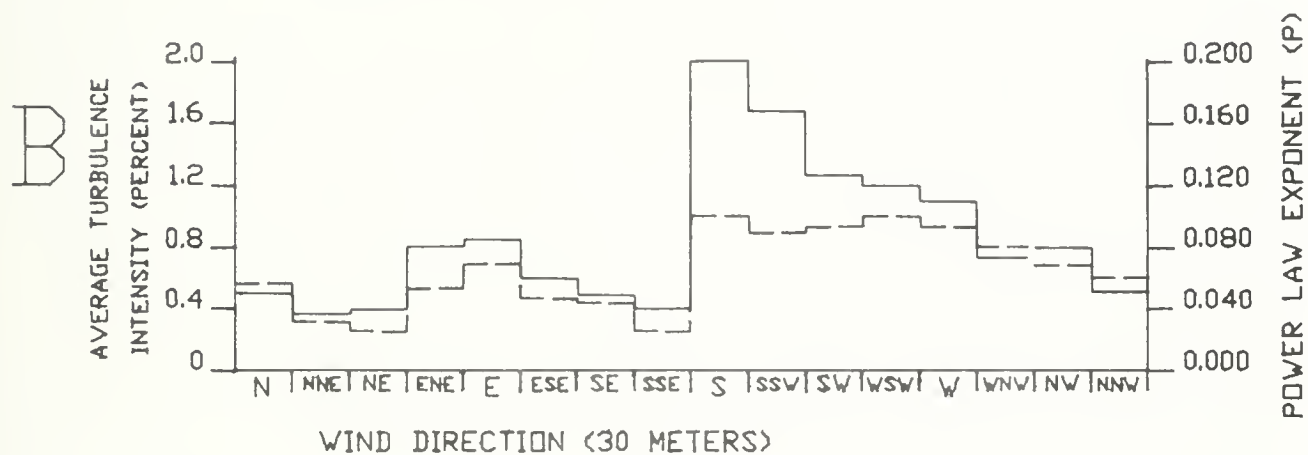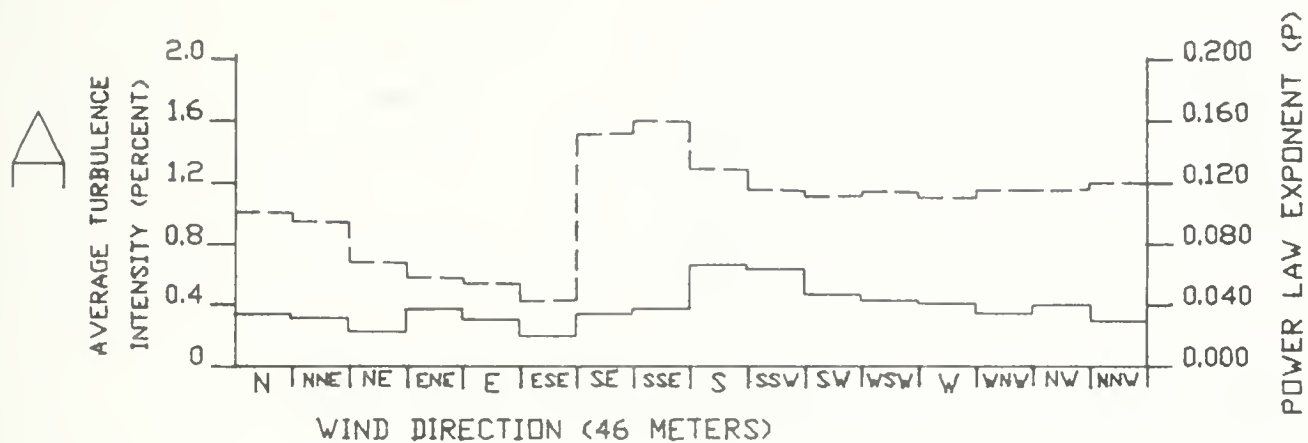
FIGURE 3-16

AVERAGE WIND SHEAR BY WIND DIRECTION CATEGORY
AT LIVINGSTON, MONTANA.
_____ =AWS   ---- = PWS
A) 30-46 METERS   B) 9-46 METERS   C) 9-30 METERS

DATA PERIOD SEP. 1985 - NOV. 1986

A-7DW50112

As was postulated for turbulence, this behavior is suspected to actually relate to wind speed rather than wind direction per se. The wind directions that have high average AWS values also tend to have high wind speeds, and vice versa. For example, AWS 9-46 values ranged from only 0.34 ms^{-1} during north-northeasterly winds up to 2.10 ms-^{1} during southerly winds. This behavior was observed fairly consistently between all tower levels.

The relationship between PWS and wind direction is less easily understood. Average PWS values for southwesterly directions are generally around 0.100; these directions are generally associated with moderate to high wind speeds, making this result consistent with behavior observed in Section 3.3.3. PWS values for directions associated with light winds tend to be more unpredictable, and vary considerably between the different levels. In veering from the northerly to southeasterly wind directions, a steady decrease in PWS 30-46 is observed, with values declining from 0.117 to 0.043. In contrast, PWS 9-30 and PWS 9-46 values are more irregular. Also, values for PWS 30-46 are much higher than for PWS 9-30 and PWS 9-46 during south-southeasterly winds. The reason for this behavior is not clear, but it is inconsequential, because winds from southeasterly directions are generally very light.

In summary, a fairly strong relationship appears to exist between wind shear and wind direction, although it is probably indirect. AWS values are generally highest for wind directions associated with the highest wind speeds, and lowest for directions associated

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with low speeds. For nearly all directions, AWS 9-30 values are much higher than AWS 30-46 values. PWS values between all levels are around 0.100 for wind directions that normally occur with moderate to high speeds. They are quite variable for directions associated with low speeds.

3.3.5 Variation of Wind Shear with Atmospheric Stability

The relationship of wind shear and atmospheric stability was investigated by examining the behavior of wind shear during each Pasquill stability category condition, as defined by the temperature difference between the 9 meter and 46 meter tower levels. The results are presented in Table 3-21. A fairly consistent relationship is present for AWS at all levels. The highest values occurred during Category E (slightly stable) conditions, and the lowest during Category A conditions. This relationship is to be expected as winds during Category A conditions are generally light, resulting in low AWS values. During Category E conditions, winds are generally much stronger, producing higher AWS values. AWS values are also fairly high during Category F conditions, which is at first surprising because these conditions are usually associated with fairly low wind speeds. However, Category F conditions are common when evening inversion formation is occurring. As was discussed previously, high wind shears may have occurred during these periods because of markedly decreased wind speeds at 9 meters, while speeds at 30 and 46 meters (above the inversion layer) were still fairly high.

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Delta T Range (Pasquill Stability Category)	Average Wind Shear					
	9-30 Meters		9-46 Meters		30-46 Meters	
	(m/s)	(P)	(m/s)	(P)	(m/s)	(P)
<-0.8°C (A-B)	0.58	0.051	0.71	0.049	0.30	0.050
-0.8 to -0.6°C (C)	0.67	0.060	0.84	0.056	0.33	0.045
-0.6 to -0.2°C (D)	0.73	0.068	0.97	0.066	0.39	0.075
-0.2 to +0.5°C (E)	1.10	0.097	1.58	0.101	0.53	0.119
+0.5 to +1.4°C (F)	0.91	0.090	1.23	0.093	0.43	0.134
>+1.4°C (G)	0.70	0.090	0.97	0.100	0.41	0.191

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Although distinct, the variations in AWS with atmospheric stability were much less pronounced than those observed with wind speed and wind direction. AWS 9-46 for example varied from 0.71 ms^{-1} during Category A conditions up to 1.58 ms^{-1} during Category E conditions. PWS values also were very low during Category A conditions, but otherwise behaved differently at the various levels. PWS 9-30 and PWS 9-46 values were highest during Category E conditions, and remained nearly as high during Category F and G conditions. By contrast, PWS 30-46 values were by far highest during Category G conditions, averaging 0.191. While high, this particular PWS value is not of concern, because wind speeds during these conditions are invariably light. In fact, during stability conditions associated with moderate to strong winds (C, D, E, and occasionally F) average PWS values were usually near or below 0.100. When wind speeds are low, small difference in speed with height (AWS) can result in large PWS values.

As with wind direction, the relationship between atmospheric stability and wind shear is an indirect one. The stability classes associated with the highest wind speeds tend to have the highest AWS values; classes with low wind speeds generally have low AWS values. Similarly, PWS values tend to be around 0.100 for stability categories associated with moderate to high wind speeds, and are more variable for classes associated with light winds. PWS 30-46 values average only 0.050 during Category A conditions, but 0.191 during Category G conditions, although both conditions are usually associated with low wind speeds. This probably occurs

because AWS 30-46 is slightly higher during Category G conditions, and this small increase in absolute shear results in a much larger PWS value because of the low wind speeds.

3.3.6 Variation of Wind Shear with Thunderstorms

At the beginning of this study, concern was expressed that the thunderstorm conditions often observed at Livingston during the summer months might contribute to severe wind shear conditions. The concern had been corroborated by several nationally publicized aviation accidents involving wind shear near the ground over the past ten years. Therefore, AWS data collected during periods that thunder was reported at the Livingston airport were compared with data taken during other periods during the months of May-September 1986 to determine whether significant differences existed. The results are presented in Table 3-22.

TABLE 3-22. SUMMARY OF WIND SHEAR AT LIVINGSTON, MONTANA
DURING THUNDERSTORM CONDITIONS

Percent Frequency of:	Wind Shear Range (m/s)					Average
	<0	0-1	1-2	2-3	3<	
AWS 9-46 during thunderstorms	8.5	51.4	32.2	6.8	1.1	0.93
AWS 9-46 overall	16.9	48.8	24.1	8.3	1.8	0.79
AWS 30-46 during thunderstorms	34.3	63.5	2.2	—	—	0.17
AWS 30-46 overall	27.6	69.5	2.7	—	—	0.19

AWS during thunderstorm conditions is similar to that observed at other times. On the average, AWS 9-46 is slightly higher, while AWS 30-46 is slightly lower. The important result is that the highest wind shear categories were actually less frequent during thunderstorm conditions. AWS 9-46 values above 3 ms^{-1} occurred 1.1% of the time during thunderstorms, versus 1.8% of the time during other periods. For AWS 30-46 values above 1 ms^{-1}, respective values are 2.2% and 2.7%. These results indicate that thunderstorm conditions are probably not an area of concern to wind developers. Also, as discussed in Section 3.2.6, the gusty winds that often occur during thunderstorm episodes do not approach the severe conditions often present during the winter months. Therefore, with the very predictable relationship shown between AWS and wind speed, wind shears during summertime thunderstorm episodes would be expected to be less than those observed during typical windy periods during the winter months.

3.3.7 Relationship Between Average 2-Minute Wind Shears and Maximum Instantaneous Wind Shear

In addition to defining the relationship of average 2-minute wind shears to other meteorological variables, defining the behavior of maximum instantaneous wind shears was also desirable. As an example, if a developer knew that the average wind shear over a 2-minute period was 2 ms^{-1}, he also would want to know the maximum instantaneous wind shear during that period. Even during periods with low average wind shears, high, short-term wind shears might occur.

To address this problem, comparisons between average wind shear and maximum instantaneous wind shear were made. Summaries of these results are presented in Table 3-23. The relationship between average wind shear and maximum instantaneous wind shear is fairly consistent; higher average shears generally result in higher maximum shears. However, some difference exists between the different levels. For example, an average wind shear between 2 and 3 ms^{-1} results in an average maximum shear of 6.21 ms^{-1} between 9 and 46 meters; 5.18 ms^{-1} between 9 and 30 meters; and only 4.62 ms^{-1} between 30 and 46 meters.

Linear regressions were performed for maximum instantaneous wind shear as a function of average wind shear. The results are presented below in Table 3-24. The maximum value of 3.95 ms^{-1} for average AWS 30-46 values between 3 and 4 ms^{-1} was not included because of its infrequent occurrence and lack of statistical significance.

TABLE 3-24.   REGRESSION OF MAXIMUM INSTANTANEOUS WIND SHEAR
             AGAINST AVERAGE 2-MINUTE WIND SHEAR

Type of Shear	Slope	Y-Intercept	R^2
AWS 9-30	1.86	0.42	0.9958
AWS 9-46	2.00	1.05	0.9894
AWS 30-46	1.69	0.64	0.9669

A very strong linear relationship exists between average 2-minute wind shear and average maximum instantaneous wind shear. Roughly

TABLE 3-23. AVERAGE MAXIMUM INSTANTANEOUS WIND SHEAR AND AVERAGE TURBULENCE
INTENSITY BY AVERAGE WIND SHEAR CATEGORIES
AT LIVINGSTON, MONTANA
DATA PERIOD SEPTEMBER 1985 - NOVEMBER 1986

Average Wind Shear (m/s)	Average Maximum Instantaneous Wind Shear 9-30 Meters (m/s)	Average Maximum Instantaneous Wind Shear 9-46 Meters (m/s)	Average Maximum Instantaneous Wind Shear 30-46 Meters (m/s)	Average Alongwind Turbulence Intensity[1] (30 meters)	Average Acrosswind Turbulence Intensity[1] (30 meters)
<0	-0.01	1.07	0.35	13.8	20.3
0-1	1.31	1.58	1.17	11.9	14.9
1-2	3.15	3.74	3.67	10.1	10.5
2-3	5.18	6.21	4.62	9.8	9.3
3-4	7.25	8.39	3.95	10.6	9.1
4-5	8.46	9.81		11.1	9.0

[1] Based on 9-46 meter wind shear.

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speaking, the maximum instantaneous wind shear during a 2-minute period is about twice the average wind shear. Thus, during windy (e.g., 25 ms^{-1}) winter days, with AWS 9-46 values around 4 ms^{-1}, maximum instantaneous shears of around 8-9 ms^{-1} would be expected. This type of information should be helpful to potential developers for analyzing worst-case shear conditions.

3.4 VARIATON OF WIND SHEAR WITH TURBULENCE INTENSITY

In the preceding analyses, the variations of wind shear and turbulence with other meteorological parameters were investigated. In general, meteorological conditions that produced an increase in turbulence intensity tended to decrease the amount of wind shear, and vice versa. An inverse relation between turbulence intensity and wind shear generally exists, as shown in Table 3-23.

Average values of turbulence intensity at 30 meters were calculated for each AWS 9-46 range that occurred during the study. Both ALT and ACT were highest during negative wind shear conditions, averaging 13.8% and 20.3% respectively. ACT shows a consistent decrease with increasing wind shear, averaging only 9.0% for shears between 4 and 5 ms^{-1}. ALT decreases to 9.8% for shears between 2 and 3 ms^{-1}, but then increases to 11.1% for shears between 4 and 5 ms^{-1}. Still, this value is at the low end of the moderate range, and indicates that during severe wind shear episodes turbulence is normally not high. In fact, during periods that the AWS 9-46 exceeded 1.0 ms^{-1}, the ALT exceeded 20% less than 5% of the time,

and exceeded 30% less than 3% of the time. In other words, most occurrences of ALT above 20% (high) were associated with AWS 9-46 values below 1 ms^{-1}.

These findings are entirely consistent with earlier results. Both wind shear and turbulence intensity correlated most strongly with wind speed. High wind speeds generally resulted in higher wind shears and lower turbulence intensities; lower wind speeds usually resulted in lower wind shears and higher turbulence intensities. These analyses indicate that conditions of high wind shear and high turbulence intensity do not generally occur simultaneously. No meteorological conditions were found that contribute to both high turbulence intensity and strong wind shear.

3.5 SUMMARIZED WIND SPEED AND DIRECTION STATISTICS

Joint frequency distributions of wind speed and wind direction were calculated by month and by season for each tower level. The seasonal distributions are presented in Appendix B; monthly results are presented in Appendix C.

Additionally, a variety of monthly wind speed, wind direction, and wind energy statistics, listed below, are presented in Appendix D:

    · Daily and monthly average wind speed and direction for each tower level.

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•   Hourly average wind speed and direction for each tower level.

•   Daily and monthly average wind energy for each tower level.

3.6   COMPARISON OF CURRENT AND HISTORICAL WIND DATA

In addition to quantifying the wind shear and turbulence
characteristics of the Livingston bench, a primary objective of
this study was to compare the summarized wind speed, wind
direction, and wind energy data with historical data collected by
MultiTech at the site between September 1980 and September 1982.
Overall, the current and historical data were very similar, as can
be seen in Table 3-25. Graphical comparisons of the data for the
30 meter level are presented in Figure 3-17. Some caution should
be used in making direct monthly comparisons, because the data
recovery percentages were not generally outstanding during either
study period.

The average annual wind speed at all tower levels was nearly
identical during both periods, and interannual variations for most
months were small, usually 1 ms^{-1} or less. The largest observed
variation occurred in March, but is of doubtful significance
because the overall data recovery for March 1986 was less than 15%.
The average differences in wind speed between the 9 meter and 46
meter levels were generally larger during the historical period; no
obvious explanation exists for this behavior. The interannual

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Average Wind Speed - September 1985 - January 1987			9.0	6.3	6.3	5.2	5.5	4.6	6.2	7.0	8.1	11.3	6.9
(9 meters) Historical	8.7	9.5	5.7	5.8	4.9	5.2	5.2	4.8	5.0	6.8	8.7	10.4	6.7 (6.2)
Average Wind Speed - September 1985 - January 1987	10.7		10.1	7.0	6.7	5.8	6.2	5.1	6.9	7.3	8.8	12.0	7.9
(30 meters) Historical	9.8	11.5	8.6	6.6	5.4	5.9	5.9	5.5	5.8	7.8	10.0	11.9	7.9 (7.6)
Average Wind Speed - September 1985 - January 1987			10.6	7.3	7.3	6.0	6.4	5.3	6.9	8.2	9.4	13.4	7.9
(46 meters) Historical	10.4	11.7	9.2	7.1	6.4	6.6	6.6	6.1	6.5	8.5	10.3	12.3	8.5 (8.0)
Average Wind Direction - September 1985 - January 1987			235	224	228	212	214	154	200	220	72	213	*
(9 meters) Historical	196	199	182	164	184	171	165	139	192	202	202	190	*
Average Wind Direction - September 1985 - January 1987			232	224	233	210	212	152	200	236	272	209	*
(30 meters) Historical	192	192	199	169	196	175	176	144	209	203	200	194	*
Average Wind Direction - September 1985 - January 1987			233	225	228	212	214	154	155	217	187	213	*
(46 meters) Historical	190	192	207	167	195	179	187	161	208	204	200	191	*
Average Wind Energy - September 1985 - January 1987			584	242	350	135	180	110	234	371	652	1240	410
(9 meters) Historical	966	1101	528	265	147	187	189	153	135	473	590	1271	500 (393)
Average Wind Energy - September 1985 - January 1987	1300		829	347	392	198	264	159	330	398	888	1580	608
(30 meters) Historical	1305	1738	707	368	199	267	270	223	189	667	846	1682	705 (611)
Average Wind Energy - September 1985 - January 1987			930	383	568	218	293	174	324	608	1057	2060	662
(46 meters) Historical	1660	1919	590	432	262	333	333	284	241	846	1058	2231	849 (661)

All wind speed values are in meters per second.
All wind direction values are in degrees.
All wind energy values are in watts per square meter.

Annual historical averages in parentheses are averages incorporating only those
months of the year for which current averages exist.
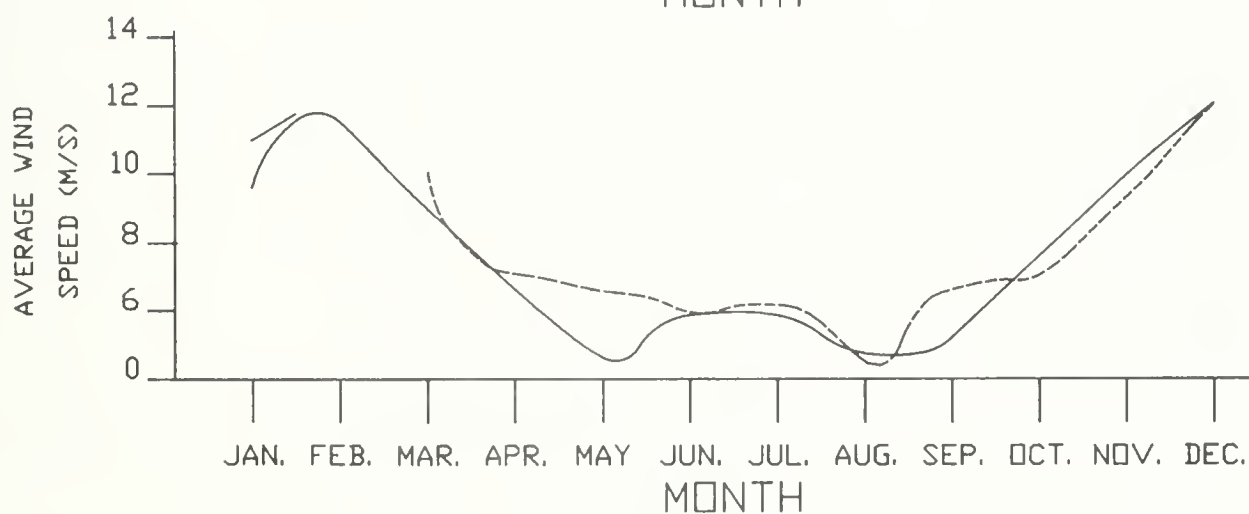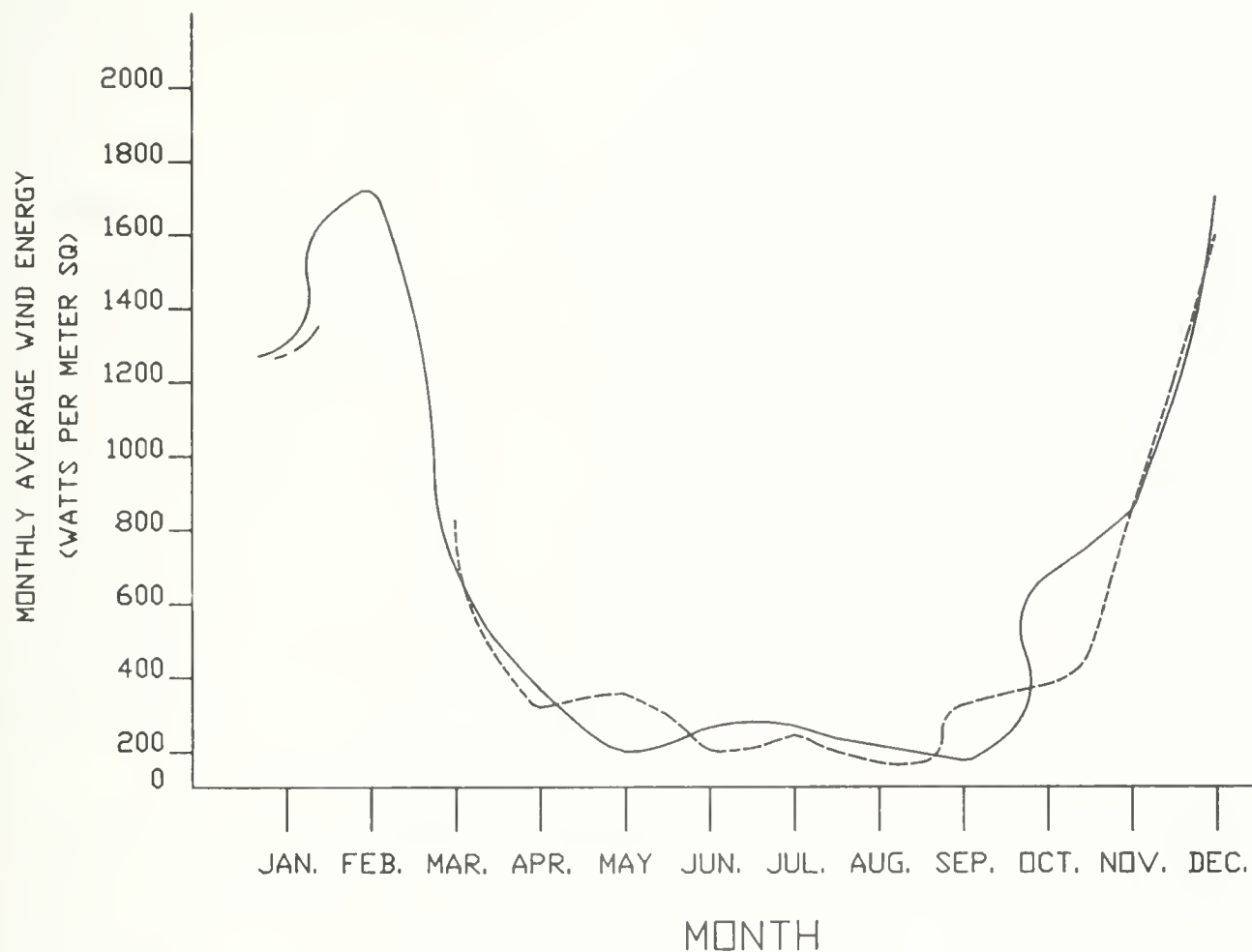
AVERAGE MONTHLY WIND SPEED AND WIND ENERGY
AT LIVINGSTON, MONTANA.
DATA FOR SEP. 1985 - JAN. 1987 (-----)
SEP. 1980 - SEP. 1982 (_____)
FIGURE 3-17

variations in monthly average wind speeds appear to be random, and show no clear pattern related to time of year.

The annual average wind direction cannot be calculated from monthly average values; however, a comparison of monthly averages from both study periods reveals similar behavior. South-southwesterly directions predominated between spring and fall; during the summer months more southerly directions often occurred. A comparison of monthly average directions for the two study periods shows, qualitatively, that wind directions tended to be slightly more southerly during the historical period. Slight differences in the alignment of the wind direction sensors and/or the 46 meter tower probably are the source of these differences.

A comparison of the wind energy statistics for both data periods shows trends very similar to those observed for wind speed. Significant interannual monthly variations were observed, but the overall annual averages were nearly identical. The greatest percent variations (e.g., 38.7% in August at 46 meters) occurred during the months that wind speeds were lowest, when small variations in wind speed result in large percentage differences in wind energy. These months are not the highest wind energy production months. By contrast, interannual variations during the windiest months (November-March) were generally on the order of 10%. Because wind energy is proportional to the cube of the wind speed, and monthly average wind energy values were calculated based on hourly wind speed data, there were several occurrences of years

with slightly higher monthly average wind speeds having slightly lower monthly average wind energy potential, and vice versa. The month of January was one example of this.

Another comparison of the summarized data was made by performing linear regressions of the monthly averages for wind speed and wind energy. The results are listed in Table 3-26.

TABLE 3-26. REGRESSION ANALYSIS OF HISTORICAL WIND DATA AGAINST CURRENT WIND DATA

	Slope	Y-Intercept	R^2 (Correlation Coefficient)
Wind Speed 9 meters	0.784	0.802	0.708
Wind Speed 30 meters	0.895	0.486	0.855
Wind Speed 46 meters	0.803	1.474	0.900
Wind Energy 9 meters	0.994	-13.4	0.936
Wind Energy 30 meters	0.913	32.7	0.926
Wind Energy 46 meters	1.020	-13.7	0.903

These regressions represent the best fit of the current data against the historical data. Overall correlations were much higher for the wind energy data than for the wind speed data. Also, the wind speed data showed an increasing correlation with height, ranging from 0.708 at 9 meters up to 0.900 at 46 meters.

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Correlation coefficients for wind energy were over 0.900 at all levels. These statistics indicate that, with the exception of wind speed data at 9 meters, the historical monthly averages were a fairly good predictor of monthly averages during the wind shear and turbulence study.

3.7 CONCLUSIONS

The analyses performed during this study provided a good characterization of the wind shear and turbulence characteristics of the Livingston site. Both were found to vary considerably with other meteorological parameters, particularly wind speed. The following paragraphs summarize the more important conclusions regarding the behavior of turbulence and wind shear at Livingston.

3.7.1 Turbulence

In general, the turbulence intensity at Livingston can be described as low to moderate, based upon Baker's classification system, and is comparable to that observed at other windy sites. It is generally highest during the summer months and lowest during the winter. A slight decrease in turbulence occurs with height, which is generally more pronounced during periods of higher wind speed. Some relation exists between turbulence intensity and the diurnal cycle; turbulence intensity tends to be highest around mid-day when solar heating is at its peak, and lowest during the evening when nocturnal temperature inversion formation is often occurring.

By far, the most reliable meteorological predictor of turbulence is wind speed. Nearly all episodes of high (>20%) turbulence intensity occurred during wind speeds insufficient to power a wind machine. At the 30-meter level, for example, wind speeds above 6 ms^{-1} were accompanied by high turbulence intensities less than 2% of the time. At speeds above 16 ms^{-1} high turbulence intensities were almost unknown. Periods with winds above 6 ms^{-1} generally had turbulence intensities of around 10%. On the average, acrosswind turbulence was greater than alongwind turbulence, but this situation was reversed at wind speeds above 10 ms^{-1}.

A strong relationship also was observed between turbulence intensity and wind direction, but this is suspected to be an indirect relationship that is primarily driven by wind speed. The lowest turbulence intensities occurred during southwesterly and easterly winds, which are generally associated with moderate to high speeds. Conversely, the highest turbulence intensities occurred with southeasterly and northerly winds, which tend to be the lightest. The high turbulence intensities present with these directions are not of great concern, because of the low wind speeds.

Similarly, the relationship observed between turbulence intensity and atmospheric stability is suspected to be largely a result of wind speed. During both very stable (Category G) and very unstable (Category A) conditions the turbulence intensity tends to be higher; both of these conditions are usually associated with low

wind speeds. Similarly, other stability categories usually have higher wind speeds, resulting in lower turbulence intensities. As was discussed previously, there does appear to be some correlation of turbulence to atmospheric stability that is not related to wind speed; at 9 meters the highest turbulence intensities occurred during Category A conditions, while at 46 meters Category G conditions produced the greatest turbulence. The effect of thunderstorm conditions on turbulence intensity also was investigated. No definite relationships were observed. During the thunderstorm season (May through September) the pattern of turbulence intensity during thunderstorm conditions was very similar to that occurring at other times. Therefore, from the standpoint of turbulence affecting machine performance, thunderstorm conditions do not seem to warrant concern.

In summary, the turbulence characteristics of Livingston appears to be favorable for wind energy development. The overall turbulence intensity can be classified as low to moderate, and is comparable to that observed at other windy sites. More importantly, periods of high turbulence intensity are generally accompanied by low (non-power producing) wind speeds. The analyses performed during this study disclosed no meteorological conditions that typically result in high turbulence intensities and high wind speeds.

3.7.2 **Wind Shear**

At Livingston, the wind shear can generally be classified as moderate, based on a comparison to that observed at other sites in terms of the power law exponent. However, in terms of the absolute wind shear (i.e., the change in meters per second of wind speed with height) conditions at Livingston can be fairly severe. This is because absolute wind shear at Livingston is a nearly linear function of wind speed, and the wind speeds at Livingston can be very high (over 25 ms^{-1}) at times, particularly during the late fall and winter months. The similarity between power law exponents at Livingston and other sites indicates similar amounts of absolute wind shear, provided that the wind speeds are similar. However, the Livingston site is subject to greater amounts of absolute wind shear than many other sites, because of the higher wind speeds that occur during the late fall and winter months. The magnitude of absolute wind shears that can occur at Livingston is important to any potential developer. Whereas most periods of high turbulence intensity occur at wind speeds insufficient to power a generator, virtually all periods of high absolute wind shear occur with high wind speeds.

In terms of the power law exponent, wind shear at Livingston shows a slight increase with height, but the absolute wind shear decreases markedly. Over 70% of the absolute wind shear between 9 and 46 meters occurs between 9 and 30 meters. Average wind shear was highest during the late fall and winter months and lowest

during the summer. This is opposite from the distribution observed for turbulence intensity. Wind shear tended to be highest during the early evening hours and lowest around mid-day. Again, this is the opposite of the pattern for turbulence intensity.

A strong relationship was observed between wind shear and wind direction. Absolute wind shear was generally strongest during southwesterly and easterly winds, and lowest during southerly and northeasterly winds. This correlation is primarily a consequence of wind speed; wind directions associated with high speeds had the highest average wind shears, and vice versa. In terms of the power law exponent, wind shears were generally near 0.100 for directions associated with moderate to strong winds, and varied considerably for other directions.

Some correlation was found between wind shear and atmospheric stability. During very stable and very unstable conditions, absolute wind shears were usually low; again, these conditions are usually present during light winds. Conversely, other stability conditions, which are usually associated with higher wind speeds, produced higher wind shears.

The impact of thunderstorm conditions on wind shear also was investigated. No significant correlation was observed; both the average and frequency distribution of wind shear were nearly identical during thunderstorm conditions and at other times. It can be stated that the strong wind shears occurring with the high

late fall and winter wind speeds are of much greater concern than the brief gusts that may occur during thunderstorms.

Potential developers need to understand the magnitude of wind shear occurring at Livingston, because the highest wind shears and highest wind speeds tend to occur simultaneously. While the wind profile (as defined by the power law exponent) is comparable to that at other sites, very high absolute wind shears can occur at Livingston because of frequent high wind speeds. Also, in a given 2-minute period with an average wind shear (X), a maximum instantaneous wind shear of 2X is likely to occur. The strong positive correlation of wind shear and wind speed demands a careful analysis of these characteristics by potential developers, to ensure that their machines are adequately designed to withstand Livingston's environment.

The correlation of wind speed, wind direction, and wind energy data obtained during the wind shear and turbulence study with historical data was generally very high. Although some interannual monthly variations occurred, overall annual averages were nearly identical.

4.0   GRANT ADMINISTRATION

Monitoring at the Livingston site commenced on September 7, 1985, and the first quarterly data report was scheduled for completion on January 15, 1986, or 45 days after the corresponding period of monitoring ended. Unfortunately, the development of computer programs to reduce the data took much longer to complete than had been originally anticipated. Consequently, the first quarterly reports were not submitted until June 30, 1986. After this date, all subsequent quarterly reports were completed on schedule.

The other major departure from the projected work schedule involved the early termination of the project. Numerous, extremely frustrating problems with the tower elevator mechanism and anemometer cups resulted in severe data losses, and made it nearly impossible to collect data during the winter months. Therefore, a decision was made in January 1987 to terminate the monitoring, seven months before the originally scheduled completion date of September 1987.

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APPENDIX A

EQUIPMENT SPECIFICATIONS

WIND DIRECTION SENSOR SPECIFICATIONS, MODEL 020

Performance

Azimuth	Electrical 0-356°*-Mechanical 0-360°
Threshold	0.6 MPH
Linearity	±1/2% of full scale
Accuracy	±3
Damping Ratio	0.4 - 0.6
Delay Distance	Less than 3 feet

*360° or 540° range is determined by the translator range card, not the Wind Direction Transducer.

Electrical Characteristics

Input Power	12 VDC at 10 MA
Output*	0-5 volts for 0-360° (or 540°)
Output Impedance	100 ohms maximum
Maximum Line Length	1500' (consult factory if longer line is to be used)

Mechanical Characteristics

Weight	1.5 lbs.
Finish	White gloss baked enamel

WIND SPEED SENSOR SPECIFICATIONS, MODEL 010

Performance Characteristics

Maximum Operating Range	0-60 meters/sec or 0-125 mph
Starting Speed	.2 meters/sec or 0.5 mph
Calibrated Range	0-50 meters/sec or 0-100 mph
Accuracy	+ or 0.15 mph
Temperature Range	-50°C to +85°C
Response	Distance constant less than 5 feet of flow

*The distance travelled by the air after a sharp edged gust has occurred for the anemometer rate to reach 63% of the new speed.

Electrical Characteristics

Power Requirements	12 VDC at 10 MA
Output Signal	11-volt pulse
Output Impedance	100 ohms maximum

Physical Characteristics

Weight	1.5 lbs.
Finish	White gloss baked enamel
Mounting Fixtures	Use with #C1120 Crossarm

APPENDIX B

SEASONAL WIND ROSES

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SPRING - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
0.0 – 0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.00
0.4 – 0.8	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
0.8 – 1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
1.2 – 1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0.01
1.6 – 2.0	174	155	250	274	289	288	236	154	177	139	151	114	91	73	133	145	2843	9.59
2.0 – 2.4	156	148	142	220	185	119	119	84	141	111	112	89	82	63	102	124	1997	6.74
2.4 – 2.8	82	96	112	103	131	77	79	62	73	81	87	80	50	66	70	72	1321	4.46
2.8 – 3.2	72	48	87	90	89	65	66	20	54	73	96	84	55	43	56	61	1059	3.57
3.2 – 3.6	51	44	49	55	65	66	42	24	45	75	116	90	58	52	62	53	947	3.19
3.6 – 4.0	42	37	58	71	62	57	26	16	46	65	110	112	72	53	42	48	917	3.09
4.0 – 4.4	24	29	63	54	68	48	27	6	41	84	145	135	79	56	30	39	928	3.13
4.4 – 4.8	36	29	54	46	66	56	37	10	24	61	169	174	64	42	16	27	940	3.17
4.8 – 5.2	37	27	69	60	85	66	26	0	21	58	204	177	76	41	30	30	980	3.31
5.2 – 5.6	35	25	54	76	75	85	38	2	25	63	232	200	93	37	16	25	1050	3.54
5.6 – 6.0	40	16	28	76	84	82	28	1	23	100	195	232	100	44	12	23	1086	3.66
6.0 – 6.4	27	19	16	70	78	70	27	4	24	114	187	261	109	47	7	39	1096	3.70
6.4 – 6.8	26	9	18	75	104	54	13	2	33	132	209	284	113	43	9	28	1161	3.92
6.8 – 7.2	28	8	23	94	123	26	7	2	14	150	210	254	147	43	6	30	1160	3.91
7.2 – 7.6	23	4	20	93	131	25	11	0	25	161	227	258	155	53	8	25	1214	4.09
7.6 – 8.0	13	1	15	97	115	10	4	1	37	155	192	244	139	45	4	30	1107	3.73
8.0 – 8.4	15	1	20	122	114	1	0	1	39	146	188	240	140	44	3	29	1112	3.75
8.4 – 8.8	5	2	29	134	110	0	0	1	59	112	142	265	151	36	5	29	1064	3.59
8.8 – 9.2	10	0	14	189	82	0	1	0	47	142	108	200	143	36	1	28	996	3.36
9.2 – 9.6	10	0	16	156	49	0	0	0	39	131	110	227	159	40	2	24	933	3.15
9.6 – 10.0	6	0	11	124	34	0	0	0	32	110	92	170	146	36	0	33	765	2.58
10.0 – 10.4	8	0	5	96	24	0	0	0	35	91	84	178	162	32	2	23	714	2.41
10.4 – 10.8	1	0	7	77	39	0	0	0	37	81	76	144	107	24	1	22	618	2.08
10.8 – 11.2	3	0	1	83	20	0	0	0	33	86	64	127	102	13	0	18	539	1.82
11.2 – 11.6	2	0	6	74	29	0	0	0	35	61	53	83	90	15	0	35	505	1.70
11.6 – 12.0	1	0	6	62	18	0	0	0	28	77	43	93	74	10	0	17	412	1.39
12.0 – 12.4	1	0	5	51	14	0	0	0	51	49	38	66	62	11	0	13	388	1.31
12.4 – 12.8	2	0	0	35	6	0	0	0	21	75	40	59	47	7	1	8	270	0.91
12.8 – 13.2	0	0	0	23	4	0	0	0	18	53	49	42	41	1	0	7	239	0.81
13.2 – 13.6	0	0	0	8	3	0	0	0	14	57	29	38	25	1	1	6	180	0.61
13.6 – 14.0	0	0	0	1	1	0	0	0	10	56	18	20	19	0	0	3	125	0.42

TABLE B-1

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SPRING - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >	=<	348/11	11/33	33/56	56/78	78/101	101/123	123/146	146/168	168/191	191/213	213/236	236/258	258/281	281/303	303/326	326/348	TOTAL FREQ	PERCENT FREQ
14.0	14.4	0	0	0	1	0	0	0	0	3	68	18	7	8	1	0	1	107	0.36
14.4	14.8	0	0	0	1	0	0	0	0	0	62	18	9	3	0	0	0	93	0.31
14.8	15.2	0	0	0	0	1	0	0	0	1	57	11	6	5	0	0	0	81	0.27
15.2	15.6	0	0	0	0	0	0	0	0	0	57	7	8	6	0	0	0	78	0.26
15.6	16.0	0	0	0	0	0	0	0	0	1	56	5	1	1	0	0	0	64	0.22
16.0	16.4	0	0	0	0	0	0	0	0	1	78	7	0	0	0	0	0	86	0.29
16.4	16.8	0	0	0	0	0	0	0	0	0	51	3	2	0	0	0	0	56	0.19
16.8	17.2	0	0	0	0	0	0	0	0	0	76	4	1	0	0	0	0	81	0.27
17.2	17.6	0	0	0	0	0	0	0	0	0	75	2	0	0	0	0	0	77	0.26
17.6	18.0	0	0	0	0	0	0	0	0	1	60	1	0	0	0	0	0	62	0.21
18.0	18.4	0	0	0	0	0	0	0	0	2	49	1	0	0	0	0	0	52	0.18
18.4	18.8	0	0	0	0	0	0	0	0	1	42	0	0	0	0	0	0	43	0.15
18.8	19.2	0	0	0	0	0	0	0	0	0	37	0	0	0	0	0	0	37	0.12
19.2	19.6	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	22	0.07
19.6	20.0	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	22	0.07
20.0	20.4	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	9	0.03
20.4	20.8	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	6	0.02
20.8	21.2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
21.2	21.6	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	4	0.01
21.6	22.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
22.0	22.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
22.4	22.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
22.8	23.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
23.2	23.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
23.6	24.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.0	24.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.4	24.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.8	25.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25.2	25.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25.6	26.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.0	26.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.4	26.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.8	27.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.2	27.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.6	28.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00

TABLE B-1 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SPRING - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >	=<	>=348 <11	11 33	33 56	56 78	78 101	101 123	123 146	146 168	168 191	191 213	213 236	236 258	258 281	281 303	303 326	326 348	TOTAL FREQ	PERCENT FREQ
28.0	28.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.4	28.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.8	29.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.2	29.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.6	30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.0	30.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.4	30.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.8	31.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.2	31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6	32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0	32.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.4	32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8	33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2	33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6	34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0	34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4	34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8	35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2	35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6	36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0	36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4	36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8	37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2	37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6	38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0	38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4	38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8	39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2	39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6	40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ		930	698	1144	2791	2298	1195	787	389	1311	3692	3878	4774	2974	1079	614	1096	29650	100.00
PERCENT FREQ		3.14	2.35	3.86	9.41	7.75	4.03	2.65	1.31	4.42	12.45	13.08	16.10	10.03	3.64	2.07	3.70	100.00	
AVERAGE WIND SPEED (M/S)		4.0	3.2	4.0	6.8	5.6	3.9	3.3	2.6	6.3	9.5	6.9	7.4	7.8	5.8	3.3	5.6		

TABLE B-1 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SUMMER - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
0.0 - 0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
0.4 - 0.8	1	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	4	0.01
0.8 - 1.2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0.00
1.2 - 1.6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.00
1.6 - 2.0	261	233	200	227	313	277	278	256	247	204	231	166	141	149	191	232	3606	8.18
2.0 - 2.4	337	324	338	442	507	399	408	334	285	302	303	304	271	294	341	294	5483	12.43
2.4 - 2.8	177	184	191	273	307	234	183	175	176	221	230	164	210	165	173	153	3216	7.29
2.8 - 3.2	137	159	166	245	240	148	164	103	101	146	193	189	175	142	110	98	2516	5.70
3.2 - 3.6	119	126	141	215	187	94	123	56	103	165	192	221	185	105	71	90	2193	4.97
3.6 - 4.0	101	89	112	146	156	103	116	62	76	148	201	238	137	71	48	56	1879	4.26
4.0 - 4.4	77	68	107	194	148	100	84	29	67	176	238	261	160	98	56	42	1980	4.49
4.4 - 4.8	65	38	95	165	148	70	52	22	54	169	275	296	166	56	38	53	1827	4.14
4.8 - 5.2	43	17	91	182	181	85	56	24	70	159	267	297	189	84	36	35	1815	4.11
5.2 - 5.6	31	12	40	208	226	102	52	18	54	185	284	248	86	95	36	33	1826	4.14
5.6 - 6.0	39	8	54	199	245	71	56	8	70	203	257	202	94	84	44	31	1830	4.15
6.0 - 6.4	23	8	37	215	240	62	27	10	86	267	285	181	86	86	20	31	1833	4.16
6.4 - 6.8	29	9	39	219	218	56	31	4	86	228	246	206	87	82	9	19	1686	3.82
6.8 - 7.2	21	0	33	149	205	64	19	10	85	261	208	264	82	79	14	17	1597	3.62
7.2 - 7.6	13	2	33	152	158	47	13	7	90	294	218	209	79	75	11	13	1538	3.49
7.6 - 8.0	11	1	19	144	125	30	9	7	106	306	220	205	75	65	8	9	1417	3.21
8.0 - 8.4	9	0	23	125	84	19	10	6	90	299	214	203	65	50	7	12	1151	2.61
8.4 - 8.8	6	0	12	111	83	16	8	5	81	295	152	148	50	51	8	9	1081	2.45
8.8 - 9.2	5	1	7	65	68	7	5	6	91	287	126	142	51	26	6	6	946	2.14
9.2 - 9.6	1	0	2	56	52	4	4	3	120	277	122	115	26	14	5	2	821	1.86
9.6 - 10.0	4	1	4	31	41	1	1	5	140	250	78	88	14	10	3	7	680	1.54
10.0 - 10.4	1	0	3	17	48	2	2	0	135	237	59	57	10	3	1	3	594	1.35
10.4 - 10.8	2	0	1	2	26	0	0	1	116	223	57	48	9	2	1	1	494	1.12
10.8 - 11.2	2	0	1	4	20	0	2	0	119	166	29	38	9	1	1	2	387	0.88
11.2 - 11.6	5	0	0	0	10	0	0	0	105	162	16	30	10	0	2	2	370	0.84
11.6 - 12.0	0	0	0	0	4	0	0	0	115	98	18	26	5	1	5	5	262	0.59
12.0 - 12.4	1	0	0	1	7	1	1	1	105	91	7	20	4	0	3	3	261	0.59
12.4 - 12.8	0	0	0	0	1	0	0	1	116	72	8	19	3	1	1	1	208	0.47
12.8 - 13.2	0	0	0	0	0	0	0	1	107	52	4	6	4	0	2	2	154	0.35
13.2 - 13.6	0	0	0	0	0	0	0	0	83	33	1	7	2	0	3	0	111	0.25
13.6 - 14.0	0	0	0	0	0	0	0	1	64	21	0	1	3	0	2	0	72	0.16

TABLE B-2

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SUMMER - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) ≥	<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
14.0	14.4	0	0	0	0	0	0	0	0	35	14	0	0	1	1	0	0	51	0.12
14.4	14.8	0	0	0	0	0	0	0	0	26	16	2	2	2	1	0	0	49	0.11
14.8	15.2	0	0	0	0	0	0	0	0	21	9	0	0	3	0	0	0	33	0.07
15.2	15.6	0	0	0	0	0	0	0	0	18	11	0	0	2	0	0	0	31	0.07
15.6	16.0	0	0	0	0	0	0	0	0	14	6	0	2	2	1	0	0	25	0.06
16.0	16.4	0	0	0	0	0	0	0	0	12	9	0	0	2	1	0	0	24	0.05
16.4	16.8	0	0	0	0	0	0	0	0	3	12	0	0	1	0	0	0	16	0.04
16.8	17.2	0	0	0	0	0	0	0	0	6	7	0	0	1	0	0	0	14	0.03
17.2	17.6	0	0	0	0	0	0	0	0	5	4	0	0	0	0	0	0	9	0.02
17.6	18.0	0	0	0	0	0	0	0	0	2	2	0	1	0	0	0	0	5	0.01
18.0	18.4	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	5	0.01
18.4	18.8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
18.8	19.2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.00
19.2	19.6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.00
19.6	20.0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.00
20.0	20.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
20.4	20.8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.00
20.8	21.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
21.2	21.6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.00
21.6	22.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
22.0	22.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
22.4	22.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
22.8	23.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
23.2	23.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
23.6	24.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.0	24.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.4	24.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.8	25.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25.2	25.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25.6	26.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.0	26.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.4	26.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.8	27.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.2	27.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.6	28.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00

TABLE B-2 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SUMMER - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S)	>=	348	11	33	56	78	101	123	146	168	191	213	236	258	281	303	326	TOTAL FREQ	PERCENT FREQ
	<	11	33	56	78	101	123	146	168	191	213	236	258	281	303	326	348		
28.0 = 28.4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.4 = 28.8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.8 = 29.2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.2 = 29.6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.6 = 30.0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.0 = 30.4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.4 = 30.8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.8 = 31.2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.2 = 31.6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6 = 32.0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0 = 32.4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.4 = 32.8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 = 33.2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2 = 33.6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 = 34.0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 = 34.4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 = 34.8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 = 35.2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 = 35.6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 = 36.0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 = 36.4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 = 36.8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 = 37.2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 = 37.6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 = 38.0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 = 38.4		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 = 38.8		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 = 39.2		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 = 39.6		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 = 40.0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ		1521	1282	1749	3787	4048	1986	1705	1148	3485	6093	4504	4564	3806	1991	1208	1231	44108	100.00
PERCENT FREQ		3.45	2.91	3.97	8.59	9.18	4.50	3.07	2.60	7.90	13.81	10.21	10.35	8.63	4.51	2.74	2.79	100.00	
AVERAGE WIND SPEED (M/S)		3.5	2.9	3.9	5.0	5.2	4.1	3.4	3.1	8.7	7.5	5.6	5.8	6.0	4.7	3.3	3.7		

TABLE B-2 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

FALL - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >	=<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
0.0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
0.4	0.8	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	3	0.00
0.8	1.2	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	3	0.00
1.2	1.6	0	0	0	0	1	0	0	17	0	0	0	0	0	0	0	1	3	0.00
1.6	2.0	340	289	326	276	333	327	261	317	321	313	352	253	224	228	291	301	4752	5.14
2.0	2.4	573	510	538	564	677	593	462	422	438	381	455	406	390	385	535	483	7812	8.45
2.4	2.8	376	322	300	353	413	333	208	224	199	221	287	293	276	246	310	250	4611	4.99
2.8	3.2	279	189	257	325	355	190	162	152	126	157	311	311	217	194	228	194	3647	3.95
3.2	3.6	209	125	199	330	356	129	129	71	84	160	297	359	257	145	150	136	3136	3.39
3.6	4.0	130	73	135	307	357	106	78	48	69	173	348	388	300	147	110	129	2898	3.14
4.0	4.4	87	28	114	318	455	138	41	33	63	187	444	512	304	123	95	98	3040	3.29
4.4	4.8	73	28	111	334	565	110	22	20	53	205	524	611	354	117	72	80	3279	3.55
4.8	5.2	57	23	87	399	564	97	23	20	57	188	571	693	361	110	42	64	3356	3.63
5.2	5.6	66	19	85	396	581	99	13	43	76	179	581	750	351	89	45	46	3419	3.70
5.6	6.0	51	20	60	403	661	70	7	17	65	155	656	846	419	94	41	41	3606	3.90
6.0	6.4	44	13	52	335	686	63	3	5	79	174	596	849	381	87	22	42	3431	3.71
6.4	6.8	51	3	45	391	752	57	8	1	82	199	605	839	394	77	17	32	3553	3.84
6.8	7.2	28	4	39	459	754	55	3	2	73	234	575	784	407	72	20	34	3543	3.83
7.2	7.6	28	1	21	472	677	41	3	2	71	247	578	697	364	62	17	32	3313	3.58
7.6	8.0	34	1	17	416	611	21	1	7	49	342	538	647	403	58	12	20	3172	3.43
8.0	8.4	30	0	15	351	574	12	1	7	76	367	532	556	402	57	10	16	3006	3.25
8.4	8.8	19	0	3	347	472	12	0	5	93	398	561	510	396	58	5	23	2902	3.14
8.8	9.2	13	1	3	294	413	14	0	2	97	466	416	474	441	64	8	13	2718	2.94
9.2	9.6	11	1	2	311	376	11	0	0	95	478	410	412	357	67	4	16	2571	2.78
9.6	10.0	7	0	0	286	345	6	0	0	81	564	424	323	324	65	2	5	2432	2.63
10.0	10.4	5	0	2	214	324	11	0	2	87	584	362	324	305	50	1	11	2278	2.46
10.4	10.8	4	0	2	177	328	1	0	2	76	535	364	218	287	39	1	8	2042	2.21
10.8	11.2	6	0	2	143	300	1	0	1	68	575	291	175	200	30	0	8	1804	1.95
11.2	11.6	5	0	2	134	282	5	0	0	80	537	159	200	182	27	0	2	1705	1.84
11.6	12.0	1	0	0	87	227	3	0	1	73	474	134	163	163	21	0	8	1418	1.53
12.0	12.4	2	1	0	60	168	2	0	0	69	446	226	94	94	21	0	4	1162	1.26
12.4	12.8	2	0	1	35	123	0	0	3	66	405	217	82	63	19	1	3	979	1.06
12.8	13.2	2	0	0	20	81	0	0	0	66	364	206	62	50	9	0	6	821	0.89
13.2	13.6	0	0	0	11	57	0	0	0	58	298	188	35	42	9	0	1	656	0.71
13.6	14.0	1	0	0	7	36	0	0	0	50	280	143	36	15	10	0	3	563	0.61

TABLE B-3

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

FALL - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
14.0	14.4	0	0	0	2	36	0	0	0	66	261	95	13	7	3	0	3	486	0.53
14.4	14.8	0	0	0	2	27	0	0	0	48	247	92	7	8	0	0	1	432	0.47
14.8	15.2	0	0	0	1	20	0	0	0	52	281	105	7	9	0	0	3	478	0.52
15.2	15.6	0	0	0	1	19	0	0	0	34	249	86	2	4	0	0	3	398	0.43
15.6	16.0	0	0	0	1	15	0	0	0	34	218	83	2	1	0	0	0	354	0.38
16.0	16.4	0	0	0	0	10	0	0	0	25	220	85	2	4	0	0	1	347	0.38
16.4	16.8	0	0	0	0	13	0	0	0	18	210	62	1	1	0	0	1	308	0.33
16.8	17.2	0	0	0	0	13	0	0	0	16	175	43	1	0	0	0	1	249	0.27
17.2	17.6	0	0	0	0	5	0	0	0	16	197	44	0	0	0	0	0	262	0.28
17.6	18.0	0	0	0	0	1	0	0	0	18	162	36	0	0	0	0	0	217	0.23
18.0	18.4	0	0	0	0	1	0	0	0	15	118	26	0	0	0	0	0	160	0.17
18.4	18.8	0	0	0	0	0	0	0	0	8	101	32	0	0	0	0	0	141	0.15
18.8	19.2	1	0	0	0	0	0	0	0	23	80	17	0	0	0	0	0	121	0.13
19.2	19.6	0	0	0	0	0	0	0	0	18	84	14	0	0	0	0	0	116	0.13
19.6	20.0	0	0	0	0	0	0	0	0	13	89	18	0	0	0	0	0	120	0.13
20.0	20.4	0	0	0	0	0	0	0	0	9	66	12	0	0	0	0	0	87	0.09
20.4	20.8	0	0	0	0	0	0	0	0	9	60	9	0	1	0	0	0	79	0.09
20.8	21.2	0	0	0	0	0	0	0	0	13	57	7	0	0	0	0	0	77	0.08
21.2	21.6	0	0	0	0	0	0	0	0	16	73	8	0	0	0	0	0	97	0.10
21.6	22.0	0	0	0	0	0	0	0	0	19	51	2	0	0	0	0	0	72	0.08
22.0	22.4	0	0	0	0	0	0	0	0	9	36	1	0	0	0	0	0	46	0.05
22.4	22.8	0	0	0	0	0	0	0	0	6	32	0	0	0	0	0	0	38	0.04
22.8	23.2	0	0	0	0	0	0	0	0	6	29	0	0	0	0	0	0	35	0.04
23.2	23.6	0	0	0	0	0	0	0	0	6	17	0	0	0	0	0	0	23	0.02
23.6	24.0	0	0	0	0	0	0	0	0	3	9	0	0	0	0	0	0	12	0.01
24.0	24.4	0	0	0	0	0	0	0	0	6	12	0	0	0	0	0	0	18	0.02
24.4	24.8	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	6	0.01
24.8	25.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25.2	25.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25.6	26.0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
26.0	26.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.4	26.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.8	27.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.2	27.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.6	28.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00

TABLE B-3 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

FALL - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
28.0 28.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.4 28.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.8 29.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.2 29.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.6 30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.0 30.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.4 30.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.8 31.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.2 31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6 32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0 32.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.4 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	2538	1650	2417	8562	13064	2506	1426	1406	3550	13423	13389	12796	8758	2767	2039	2123	92414	100.00
PERCENT FREQ	2.75	1.79	2.62	9.26	14.14	2.71	1.54	1.52	3.84	14.52	14.49	13.85	9.48	2.99	2.21	2.30	100.00	
AVERAGE WIND SPEED (M/S)	3.5	2.7	3.4	6.3	6.9	3.6	2.7	2.8	7.9	10.7	7.7	6.6	5.9	5.1	3.2	3.8		

TABLE B-3 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

WINTER – 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	>=348 / <11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
0.0 / 0.4	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	5	0.04
0.4 / 0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
0.8 / 1.2	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	4	0.03
1.2 / 1.6	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0.01
1.6 / 2.0	25	18	19	8	14	7	13	22	35	19	27	32	17	22	29	28	335	2.41
2.0 / 2.4	22	17	9	7	6	8	8	12	8	7	15	19	33	46	37	23	277	2.00
2.4 / 2.8	8	11	4	1	3	3	8	4	3	11	5	8	22	40	32	25	188	1.35
2.8 / 3.2	8	10	3	1	1	2	3	1	2	3	1	16	21	33	30	14	149	1.07
3.2 / 3.6	10	6	1	0	0	0	0	0	1	7	14	16	24	24	27	16	141	1.02
3.6 / 4.0	6	5	0	0	0	1	1	2	3	4	9	21	25	21	23	13	133	0.96
4.0 / 4.4	5	3	1	0	0	0	0	0	0	2	13	25	16	18	15	10	108	0.78
4.4 / 4.8	6	1	0	0	0	0	0	0	0	3	18	24	25	14	19	16	126	0.91
4.8 / 5.2	3	1	0	0	0	0	0	0	0	5	17	37	23	12	9	7	114	0.82
5.2 / 5.6	2	0	0	0	0	0	0	0	1	2	25	49	29	11	7	14	139	1.00
5.6 / 6.0	1	0	0	0	0	0	0	0	2	8	30	77	33	6	13	6	175	1.26
6.0 / 6.4	5	0	0	0	0	0	0	0	0	16	45	100	46	2	3	13	232	1.67
6.4 / 6.8	2	0	0	0	0	0	0	0	0	12	60	123	38	2	1	14	252	1.82
6.8 / 7.2	1	0	0	0	0	0	0	0	2	28	62	137	39	1	3	10	281	2.02
7.2 / 7.6	1	0	0	0	0	0	0	0	4	42	106	190	33	0	1	22	397	2.86
7.6 / 8.0	4	0	0	0	0	0	0	0	3	67	103	206	32	0	1	23	438	3.16
8.0 / 8.4	7	0	0	0	0	0	0	0	3	92	137	209	26	1	0	19	495	3.57
8.4 / 8.8	6	0	0	0	0	0	0	0	7	90	139	223	17	0	0	25	503	3.62
8.8 / 9.2	8	0	0	0	0	0	0	0	1	82	142	231	18	0	0	22	506	3.65
9.2 / 9.6	3	0	0	0	0	0	0	0	2	92	151	217	19	0	1	15	504	3.63
9.6 / 10.0	5	0	0	0	0	0	0	0	3	104	166	153	18	0	0	20	468	3.37
10.0 / 10.4	0	0	0	0	0	0	0	0	1	103	156	153	20	1	0	0	434	3.13
10.4 / 10.8	0	0	0	0	0	0	0	0	2	135	145	134	18	0	0	5	440	3.17
10.8 / 11.2	0	0	0	0	0	0	0	0	3	152	126	90	17	2	0	1	389	2.80
11.2 / 11.6	0	0	0	0	0	0	0	0	5	158	127	70	6	0	0	1	362	2.61
11.6 / 12.0	0	0	0	0	0	0	0	0	3	208	106	45	5	2	0	0	369	2.66
12.0 / 12.4	0	0	0	0	0	0	0	0	5	212	97	46	8	1	0	0	369	2.66
12.4 / 12.8	0	0	0	0	0	0	0	0	6	207	105	51	9	0	0	0	378	2.72
12.8 / 13.2	0	0	0	0	0	0	0	0	9	221	81	36	9	0	0	0	356	2.56
13.2 / 13.6	0	0	0	0	0	0	0	0	12	255	70	21	10	0	0	0	368	2.65
13.6 / 14.0	0	0	0	0	0	0	0	0	15	248	70	18	3	0	0	0	354	2.55

TABLE B-4

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

WINTER - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >	=<	348 11	11 33	33 56	56 78	78 101	101 123	123 146	146 168	168 191	191 213	213 236	236 258	258 281	281 303	303 326	326 348	TOTAL FREQ	PERCENT FREQ
14.0	14.4	0	0	0	0	0	0	0	0	20	259	66	17	1	0	0	0	363	2.62
14.4	14.8	0	0	0	0	0	0	0	0	21	216	53	10	4	0	0	0	304	2.19
14.8	15.2	0	0	0	0	0	0	0	0	29	228	36	8	1	0	0	0	302	2.18
15.2	15.6	0	0	0	0	0	0	0	0	27	205	24	6	1	0	0	0	263	1.89
15.6	16.0	0	0	0	0	0	0	0	0	32	213	14	7	0	0	0	0	266	1.92
16.0	16.4	0	0	0	0	0	0	0	0	31	192	12	4	0	0	0	0	239	1.72
16.4	16.8	0	0	0	0	0	0	0	0	48	199	10	2	0	0	0	0	259	1.87
16.8	17.2	0	0	0	0	0	0	0	0	38	181	11	2	0	0	0	0	232	1.67
17.2	17.6	0	0	0	0	0	0	0	0	54	168	5	0	0	0	0	0	227	1.64
17.6	18.0	0	0	0	0	0	0	0	0	54	183	5	1	0	0	0	0	243	1.75
18.0	18.4	0	0	0	0	0	0	0	0	59	150	10	0	0	0	0	0	219	1.58
18.4	18.8	0	0	0	0	0	0	0	0	53	141	4	1	0	0	0	0	199	1.43
18.8	19.2	0	0	0	0	0	0	0	0	63	95	4	0	0	0	0	0	162	1.17
19.2	19.6	0	0	0	0	0	0	0	0	50	98	2	0	0	0	0	0	150	1.08
19.6	20.0	0	0	0	0	0	0	0	0	48	71	2	0	0	0	0	0	121	0.87
20.0	20.4	0	0	0	0	0	0	0	0	47	54	0	0	0	0	0	0	101	0.73
20.4	20.8	0	0	0	0	0	0	0	0	38	37	2	0	0	0	0	0	77	0.55
20.8	21.2	0	0	0	0	0	0	0	0	34	25	1	0	0	0	0	0	60	0.43
21.2	21.6	0	0	0	0	0	0	0	0	28	27	1	0	0	0	0	0	56	0.40
21.6	22.0	0	0	0	0	0	0	0	0	30	26	1	0	0	0	0	0	57	0.41
22.0	22.4	0	0	0	0	0	0	0	0	21	10	0	0	0	0	0	0	31	0.22
22.4	22.8	0	0	0	0	0	0	0	0	20	6	0	0	0	0	0	0	26	0.19
22.8	23.2	0	0	0	0	0	0	0	0	26	7	0	0	0	0	0	0	33	0.24
23.2	23.6	0	0	0	0	0	0	0	0	20	8	0	0	0	0	0	0	28	0.20
23.6	24.0	0	0	0	0	0	0	0	0	10	6	0	0	0	0	0	0	16	0.12
24.0	24.4	0	0	0	0	0	0	0	0	7	4	0	0	0	0	0	0	11	0.08
24.4	24.8	0	0	0	0	0	0	0	0	5	5	0	0	0	0	0	0	10	0.07
24.8	25.2	0	0	0	0	0	0	0	0	6	2	0	0	0	0	0	0	8	0.06
25.2	25.6	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	8	0.06
25.6	26.0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	6	0.04
26.0	26.4	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	5	0.04
26.4	26.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.8	27.2	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	4	0.03
27.2	27.6	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0.01
27.6	28.0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.01

TABLE B-4 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA

WINTER - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
28.0 – 28.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.4 – 28.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.8 – 29.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.2 – 29.6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.01
29.6 – 30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.0 – 30.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.4 – 30.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.8 – 31.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.2 – 31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6 – 32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0 – 32.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.4 – 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 – 33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2 – 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 – 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 – 34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 – 34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 – 35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 – 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 – 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 – 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 – 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 – 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 – 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 – 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 – 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 – 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 – 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 – 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 – 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	138	66	37	17	24	21	33	41	1071	5430	2631	2834	667	258	251	362	13881	100.00
PERCENT FREQ	0.99	0.48	0.27	0.12	0.17	0.15	0.24	0.30	7.72	39.12	18.95	20.42	4.81	1.86	1.81	2.61	100.00	
AVERAGE WIND SPEED (M/S)	4.5	2.6	2.2	2.1	2.1	2.3	2.3	2.1	17.6	14.2	10.2	8.6	6.8	3.5	3.5	5.9		

TABLE B-4 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

ANNUAL - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
0.0	0.4	0	0	1	0	0	0	0	0	2	3	0	0	0	0	0	0	6	0.00
0.4	0.8	2	2	0	0	0	0	1	2	0	0	0	0	0	0	0	0	7	0.00
0.8	1.2	1	0	0	0	0	0	1	1	1	3	1	0	0	0	0	0	8	0.00
1.2	1.6	0	1	0	0	1	0	0	1	1	1	1	0	0	0	1	2	8	0.00
1.6	2.0	800	695	795	785	949	899	788	749	780	675	761	565	473	472	644	706	11536	6.41
2.0	2.4	1088	999	1027	1233	1375	1119	997	852	872	801	885	818	776	788	1015	924	15569	8.65
2.4	2.8	643	613	607	730	854	647	478	465	451	534	609	545	558	517	585	500	9336	5.19
2.8	3.2	496	406	513	661	685	405	395	276	283	379	601	600	468	412	424	367	7371	4.09
3.2	3.6	389	295	390	600	608	289	295	151	233	407	619	686	524	326	310	295	6417	3.56
3.6	4.0	279	204	305	524	575	267	212	128	194	390	663	759	534	319	223	246	5827	3.24
4.0	4.4	193	128	285	566	671	286	184	68	180	449	877	933	559	292	196	189	6056	3.36
4.4	4.8	180	96	275	545	779	236	143	52	144	438	978	1105	609	257	159	176	6172	3.43
4.8	5.2	140	68	232	641	830	248	101	46	132	410	1076	1204	649	249	103	136	6265	3.48
5.2	5.6	134	56	153	680	882	286	107	62	171	429	1095	1247	675	231	108	118	6434	3.57
5.6	6.0	131	44	137	678	990	223	62	29	175	466	1166	1442	733	235	85	101	6697	3.72
6.0	6.4	99	40	107	620	1004	195	61	17	191	571	1074	1497	742	220	41	113	6592	3.66
6.4	6.8	108	21	107	685	1074	167	40	7	200	571	1082	1510	740	208	41	91	6652	3.69
6.8	7.2	78	12	92	702	1082	145	23	12	177	673	1065	1384	814	195	40	87	6581	3.66
7.2	7.6	65	7	69	717	966	113	23	9	204	744	1131	1350	752	190	34	88	6462	3.59
7.6	8.0	62	3	56	657	851	61	15	9	178	870	1047	1271	777	168	24	85	6134	3.41
8.0	8.4	61	1	67	598	772	32	9	13	200	904	1009	1136	716	152	21	73	5764	3.20
8.4	8.8	36	2	29	592	665	28	5	11	246	895	968	1123	706	145	16	83	5550	3.08
8.8	9.2	36	0	26	548	563	21	5	5	267	966	788	1015	717	130	14	65	5166	2.87
9.2	9.6	25	2	15	523	477	13	1	5	281	957	769	950	623	117	9	62	4829	2.68
9.6	10.0	22	0	9	441	420	6	2	0	249	1009	741	727	545	107	6	61	4345	2.41
10.0	10.4	14	0	10	327	396	11	0	1	240	1005	649	709	535	83	5	35	4020	2.23
10.4	10.8	7	0	10	256	393	1	0	2	235	979	622	539	450	61	3	36	3594	2.00
10.8	11.2	11	0	4	230	340	5	0	2	207	950	508	424	349	57	1	29	3119	1.73
11.2	11.6	12	0	8	208	321	3	0	1	230	938	500	335	304	42	0	40	2942	1.63
11.6	12.0	2	0	8	149	249	2	0	0	209	829	392	290	262	38	1	30	2461	1.37
12.0	12.4	4	1	5	112	189	0	1	1	241	824	365	205	183	30	0	20	2180	1.21
12.4	12.8	4	0	0	70	130	0	0	4	200	737	353	184	124	14	2	12	1835	1.02
12.8	13.2	2	0	5	43	85	0	0	1	176	694	310	120	106	12	1	15	1570	0.87
13.2	13.6	0	0	0	19	60	0	0	0	148	642	242	99	84	14	0	7	1315	0.73
13.6	14.0	1	0	0	8	37	0	0	1	120	602	232	62	38	7	0	6	1114	0.62

TABLE B-5

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

ANNUAL - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) > / =<	>= 348 / < 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
14.0 / 14.4	0	0	3	3	36	0	0	0	124	602	179	37	17	5	0	4	1007	0.56
14.4 / 14.8	0	0	3	3	27	0	0	0	95	541	165	28	17	1	0	1	878	0.49
14.8 / 15.2	0	0	1	1	21	0	0	0	103	575	152	21	18	0	0	3	894	0.50
15.2 / 15.6	0	0	1	1	19	0	0	0	79	522	117	16	13	0	0	3	770	0.43
15.6 / 16.0	0	0	1	1	15	0	0	1	81	493	102	12	4	0	0	0	709	0.39
16.0 / 16.4	0	0	1	0	10	0	0	0	69	499	104	6	6	1	0	1	696	0.39
16.4 / 16.8	1	0	0	0	13	0	0	0	69	472	75	6	2	1	0	1	639	0.35
16.8 / 17.2	0	0	0	0	13	0	0	0	60	439	58	4	1	0	0	1	576	0.32
17.2 / 17.6	0	0	0	0	5	0	0	0	75	444	51	0	0	0	0	0	575	0.32
17.6 / 18.0	0	0	0	0	1	0	0	0	75	407	42	1	1	0	0	0	527	0.29
18.0 / 18.4	0	0	0	0	1	0	0	0	76	322	37	0	0	0	0	0	436	0.24
18.4 / 18.8	0	0	0	0	0	0	0	0	62	285	36	1	0	0	0	0	384	0.21
18.8 / 19.2	1	0	0	0	0	0	0	0	86	212	21	1	0	0	0	0	321	0.18
19.2 / 19.6	0	0	0	0	0	0	0	0	69	204	16	0	0	0	0	0	289	0.16
19.6 / 20.0	0	0	0	0	0	0	0	0	61	182	20	1	0	0	0	0	264	0.15
20.0 / 20.4	0	0	0	0	0	0	0	0	56	129	12	0	0	0	0	0	197	0.11
20.4 / 20.8	0	0	0	0	0	0	0	0	48	103	11	0	1	0	0	0	163	0.09
20.8 / 21.2	0	0	0	0	0	0	0	0	47	83	8	0	0	0	0	0	138	0.08
21.2 / 21.6	0	0	0	0	0	0	0	0	45	104	9	0	0	0	0	0	158	0.09
21.6 / 22.0	0	0	0	0	0	0	0	0	49	77	3	0	0	0	0	0	129	0.07
22.0 / 22.4	0	0	0	0	0	0	0	0	30	46	1	0	0	0	0	0	77	0.04
22.4 / 22.8	0	0	0	0	0	0	0	0	26	38	0	0	0	0	0	0	64	0.04
22.8 / 23.2	0	0	0	0	0	0	0	0	32	36	0	0	0	0	0	0	68	0.04
23.2 / 23.6	0	0	0	0	0	0	0	0	26	25	0	0	0	0	0	0	51	0.03
23.6 / 24.0	0	0	0	0	0	0	0	0	13	15	0	0	0	0	0	0	28	0.02
24.0 / 24.4	0	0	0	0	0	0	0	0	13	16	0	0	0	0	0	0	29	0.02
24.4 / 24.8	0	0	0	0	0	0	0	0	9	7	0	0	0	0	0	0	16	0.01
24.8 / 25.2	0	0	0	0	0	0	0	0	6	2	0	0	0	0	0	0	8	0.00
25.2 / 25.6	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	8	0.00
25.6 / 26.0	0	0	0	0	0	0	0	0	3	4	0	0	0	0	0	0	7	0.00
26.0 / 26.4	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	5	0.00
26.4 / 26.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.8 / 27.2	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	4	0.00
27.2 / 27.6	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0.00
27.6 / 28.0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00

TABLE B-5 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

ANNUAL - 9 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<	348 11	11 33	33 56	56 78	78 101	101 123	123 146	146 168	168 191	191 213	213 236	236 258	258 281	281 303	303 326	326 348	TOTAL FREQ	PERCENT FREQ
28.0	28.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.4	28.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.8	29.2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
29.2	29.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.6	30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.0	30.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.4	30.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.8	31.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.03
31.2	31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6	32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0	32.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.4	32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8	33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2	33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6	34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0	34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4	34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8	35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2	35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6	36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0	36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4	36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8	37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2	37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6	38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0	38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4	38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8	39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2	39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6	40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ		5127	3696	5347	15157	19434	5708	3951	2984	9417	28638	24402	24968	16205	6095	4112	4812	180053	100.00
PERCENT FREQ		2.85	2.05	2.97	8.42	10.79	3.17	2.19	1.66	5.23	15.91	13.55	13.87	9.00	3.39	2.28	2.67	100.00	
AVERAGE WIND SPEED (M/S)		3.5	2.9	3.7	6.1	6.5	3.8	3.1	2.9	9.1	10.5	7.4	6.8	6.8	5.0	3.3	4.3		

TABLE B-5 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SPRING - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348/11	11/33	33/56	56/78	78/101	101/123	123/146	146/168	168/191	191/213	213/236	236/258	258/281	281/303	303/326	326/348	TOTAL FREQ	PERCENT FREQ
0.0/0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
0.4/0.8	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.00
0.8/1.2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2	0.01
1.2/1.6	28	39	25	58	58	15	18	31	18	25	31	17	15	19	20	16	433	1.48
1.6/2.0	165	164	298	256	231	121	112	88	103	157	125	130	138	98	162	154	2502	8.52
2.0/2.4	99	105	138	149	123	68	35	40	68	78	90	87	78	66	90	83	1397	4.76
2.4/2.8	73	66	89	152	74	47	24	31	49	75	69	85	66	49	46	78	1073	3.66
2.8/3.2	49	65	88	90	75	46	22	25	62	73	62	74	49	52	48	44	924	3.15
3.2/3.6	44	42	58	56	66	51	21	12	36	62	77	93	54	51	50	53	826	2.81
3.6/4.0	42	26	37	53	82	42	13	8	30	67	79	105	56	39	59	41	788	2.68
4.0/4.4	48	23	45	54	43	41	11	11	31	54	100	119	70	48	38	30	780	2.66
4.4/4.8	25	27	50	64	59	38	5	13	24	38	119	179	86	37	29	36	851	2.90
4.8/5.2	28	31	72	45	69	43	9	8	32	54	163	157	66	37	27	31	856	2.92
5.2/5.6	22	24	57	53	61	50	12	5	26	48	155	163	65	36	20	21	818	2.79
5.6/6.0	33	18	23	79	77	78	6	3	20	44	155	172	72	30	6	29	845	2.88
6.0/6.4	27	15	14	78	115	56	8	4	27	68	172	199	82	26	3	24	918	3.13
6.4/6.8	41	15	29	79	96	48	13	1	26	108	141	184	84	36	10	23	934	3.18
6.8/7.2	24	11	18	77	89	38	6	2	19	108	170	225	119	27	6	25	964	3.28
7.2/7.6	27	3	13	76	75	46	2	1	28	121	190	218	106	35	4	35	980	3.34
7.6/8.0	25	9	19	96	103	35	3	1	37	135	160	248	112	29	7	32	1042	3.55
8.0/8.4	18	3	19	97	112	30	1	0	41	142	193	255	141	40	6	21	1115	3.80
8.4/8.8	15	5	28	107	89	12	3	1	48	142	223	236	152	35	4	30	1117	3.81
8.8/9.2	5	1	21	147	116	4	0	0	40	131	182	248	128	27	7	38	1108	3.78
9.2/9.6	6	1	13	142	71	4	1	0	53	110	142	222	113	5	4	29	903	3.08
9.6/10.0	4	1	16	183	34	0	0	1	64	127	134	219	137	21	1	37	967	3.29
10.0/10.4	2	0	12	149	19	0	1	0	50	117	105	205	136	13	1	30	844	2.88
10.4/10.8	2	0	14	148	27	0	0	0	62	94	92	201	137	16	2	27	813	2.77
10.8/11.2	0	0	7	89	22	0	0	0	61	86	104	191	128	10	2	24	728	2.48
11.2/11.6	1	0	6	108	22	0	0	0	54	83	75	159	108	9	2	19	657	2.24
11.6/12.0	0	0	7	90	13	0	0	0	51	67	69	150	91	7	1	25	569	1.94
12.0/12.4	1	0	5	94	10	0	0	0	61	59	80	124	107	6	1	25	562	1.91
12.4/12.8	0	0	4	82	15	0	0	0	47	48	65	110	70	4	0	13	484	1.65
12.8/13.2	1	0	6	68	20	0	0	0	32	53	45	88	58	3	1	26	403	1.37
13.2/13.6	0	0	8	56	6	0	0	0	38	53	57	74	53	1	0	12	368	1.25
13.6/14.0	0	0	3	42	9	0	0	0	69	41	41	67	46	0	0	12	328	1.12

TABLE B-6

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SPRING - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / =<	>= 348 / < 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
14.0 / 14.4	0	0	1	27	6	0	0	0	15	57	30	52	28	0	1	9	226	0.77
14.4 / 14.8	0	0	3	7	5	0	0	0	23	45	28	34	17	1	0	9	172	0.59
14.8 / 15.2	0	0	0	9	0	0	0	0	23	56	15	23	13	0	0	8	147	0.50
15.2 / 15.6	0	0	0	4	1	0	0	0	19	65	12	21	13	0	0	5	140	0.48
15.6 / 16.0	0	0	0	1	0	0	0	0	19	51	10	15	8	0	0	2	106	0.36
16.0 / 16.4	0	0	0	0	1	0	0	0	8	61	6	15	8	1	0	1	92	0.31
16.4 / 16.8	0	0	0	0	1	0	0	0	4	46	11	6	4	0	0	0	71	0.24
16.8 / 17.2	0	0	0	0	0	0	0	0	1	48	7	4	1	1	0	0	61	0.21
17.2 / 17.6	0	0	0	0	0	0	0	0	10	51	4	3	1	0	0	0	60	0.20
17.6 / 18.0	0	0	0	0	0	0	0	0	0	30	2	2	0	0	0	0	34	0.12
18.0 / 18.4	0	0	0	0	0	0	0	0	3	43	3	0	0	0	0	0	49	0.17
18.4 / 18.8	0	0	0	0	0	0	0	0	2	34	0	2	0	0	0	0	38	0.13
18.8 / 19.2	0	0	0	0	0	0	0	0	0	36	1	1	0	0	0	0	38	0.13
19.2 / 19.6	0	0	0	0	0	0	0	0	0	36	1	0	0	0	0	0	37	0.13
19.6 / 20.0	0	0	0	0	0	0	0	0	1	28	0	0	0	0	0	0	29	0.10
20.0 / 20.4	0	0	0	0	0	0	0	0	3	29	0	0	0	0	0	0	32	0.11
20.4 / 20.8	0	0	0	0	0	0	0	0	2	18	0	0	0	0	0	0	20	0.07
20.8 / 21.2	0	0	0	0	0	0	0	0	1	24	0	0	0	0	0	0	25	0.09
21.2 / 21.6	0	0	0	0	0	0	0	0	2	15	0	0	0	0	0	0	17	0.06
21.6 / 22.0	0	0	0	0	0	0	0	0	1	14	0	0	0	0	0	0	15	0.05
22.0 / 22.4	0	0	0	0	0	0	0	0	3	13	0	0	0	0	0	0	16	0.05
22.4 / 22.8	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	14	0.05
22.8 / 23.2	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	7	0.02
23.2 / 23.6	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0.01
23.6 / 24.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.0 / 24.4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
24.4 / 24.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.8 / 25.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25.2 / 25.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25.6 / 26.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.0 / 26.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.4 / 26.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.8 / 27.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.2 / 27.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.6 / 28.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00

TABLE B-6 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SPRING - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S)	>= 348 < 11	11 33	33 56	56 78	78 101	101 123	123 146	146 168	168 191	191 213	213 236	236 258	258 281	281 303	303 326	326 348	TOTAL FREQ	PERCENT FREQ
28.0 - 28.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.4 - 28.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.8 - 29.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.2 - 29.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.6 - 30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.0 - 30.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.4 - 30.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.8 - 31.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.2 - 31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6 - 32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0 - 32.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.4 - 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 - 33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2 - 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 - 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 - 34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 - 34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 - 35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 - 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 - 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 - 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 - 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 - 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 - 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 - 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 - 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 - 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 - 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 - 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 - 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	853	693	1247	3166	2094	924	325	286	1497	3534	3795	5173	3016	924	658	1165	29350	100.00
PERCENT FREQ	2.91	2.36	4.25	10.79	7.13	3.15	1.11	0.97	5.10	12.04	12.93	17.63	10.28	3.15	2.24	3.97	100.00	
AVERAGE WIND SPEED (M/S)	4.0	3.3	4.5	7.6	5.9	4.6	3.2	2.7	8.5	10.0	7.6	8.1	8.2	5.4	3.5	6.3		

TABLE B-6 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SUMMER - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
0.0	0.4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.00
0.4	0.8	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.00
0.8	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
1.2	1.6	356	375	340	320	346	229	190	245	287	290	322	325	313	284	297	281	4800	10.96
1.6	2.0	212	197	228	297	306	186	159	137	135	156	275	195	212	204	167	144	3210	7.33
2.0	2.4	152	130	178	279	258	135	87	91	97	160	239	197	186	130	111	108	2538	5.79
2.4	2.8	130	122	153	257	225	122	76	63	94	129	189	183	172	140	90	82	2227	5.08
2.8	3.2	101	115	134	179	156	77	57	58	71	131	167	219	173	88	81	70	1877	4.28
3.2	3.6	100	98	119	151	135	55	56	36	70	149	185	198	159	91	57	69	1730	3.95
3.6	4.0	79	101	108	163	124	83	67	36	72	157	235	197	145	88	39	49	1764	4.03
4.0	4.4	49	62	114	143	109	90	48	17	56	157	232	252	121	68	28	37	1613	3.68
4.4	4.8	35	38	93	146	124	96	30	8	52	168	253	268	134	52	46	31	1588	3.63
4.8	5.2	30	16	81	161	120	102	30	12	58	158	257	274	166	45	23	37	1575	3.60
5.2	5.6	27	9	74	161	130	85	27	14	58	179	258	251	145	55	19	31	1526	3.48
5.6	6.0	19	4	48	206	182	65	18	11	55	198	263	280	184	62	25	33	1666	3.80
6.0	6.4	18	4	44	224	231	63	28	4	75	214	265	269	209	58	15	37	1760	4.02
6.4	6.8	22	6	41	219	196	48	10	6	97	252	209	220	165	48	6	26	1527	3.49
6.8	7.2	17	2	42	184	177	52	15	6	94	253	220	209	215	56	10	18	1578	3.60
7.2	7.6	13	2	33	140	184	47	8	9	99	279	213	232	211	45	5	18	1516	3.46
7.6	8.0	5	0	40	126	182	26	7	4	92	289	183	208	202	49	11	12	1436	3.28
8.0	8.4	6	0	24	143	165	32	13	5	101	297	162	148	174	35	8	8	1309	2.99
8.4	8.8	5	0	32	123	151	38	6	5	95	258	134	141	166	37	10	10	1244	2.84
8.8	9.2	3	0	18	104	104	28	3	10	122	268	128	127	127	22	7	7	1064	2.43
9.2	9.6	3	0	13	77	53	22	1	5	96	243	76	91	107	21	4	7	847	1.93
9.6	10.0	3	0	9	56	51	17	1	3	139	218	69	86	95	10	3	5	790	1.80
10.0	10.4	3	0	6	38	65	6	3	4	151	212	51	75	62	7	2	7	698	1.59
10.4	10.8	3	0	5	29	28	2	1	0	146	198	37	61	55	7	3	4	590	1.35
10.8	11.2	3	0	4	13	33	0	0	0	150	162	27	60	44	8	0	1	541	1.24
11.2	11.6	1	0	2	3	30	1	0	3	147	119	25	46	30	4	1	2	459	1.05
11.6	12.0	0	0	1	2	18	0	0	0	125	112	5	34	26	3	1	4	340	0.78
12.0	12.4	1	0	0	1	14	0	0	0	154	91	11	18	19	3	2	4	338	0.77
12.4	12.8	0	0	0	0	9	0	0	0	147	71	7	14	19	4	1	3	296	0.68
12.8	13.2	0	0	0	0	4	0	0	0	136	40	4	12	21	4	0	3	256	0.58
13.2	13.6	0	0	0	0	7	0	0	1	121		3	12	11	4		4	203	0.46

TABLE B-7

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SUMMER - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) > / =<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
14.0 - 14.4	0	0	0	0	2	0	1	0	138	43	2	8	10	1	0	1	206	0.47
14.4 - 14.8	0	0	0	0	7	0	0	0	100	33	1	8	4	2	0	0	155	0.35
14.8 - 15.2	0	0	0	0	0	0	0	0	78	33	0	2	5	1	0	2	121	0.28
15.2 - 15.6	0	0	0	0	0	0	0	0	62	6	1	2	2	2	0	0	75	0.17
15.6 - 16.0	0	0	0	0	0	0	0	1	58	8	0	2	2	2	0	0	73	0.17
16.0 - 16.4	0	0	0	0	0	0	0	0	32	6	1	2	1	0	0	0	42	0.10
16.4 - 16.8	0	0	0	0	0	0	0	1	33	3	0	3	0	0	0	0	40	0.09
16.8 - 17.2	0	0	0	0	0	0	0	0	30	5	0	2	0	1	0	0	38	0.09
17.2 - 17.6	0	0	0	0	0	0	0	0	27	7	0	0	1	1	0	0	36	0.08
17.6 - 18.0	0	0	0	0	0	0	0	1	15	3	0	2	2	0	0	0	23	0.05
18.0 - 18.4	0	0	0	0	0	0	0	0	11	4	0	2	0	0	0	0	17	0.04
18.4 - 18.8	0	0	0	0	0	0	0	0	7	2	0	2	0	0	0	0	11	0.03
18.8 - 19.2	0	0	0	0	0	0	0	0	6	6	0	0	1	0	0	0	13	0.03
19.2 - 19.6	0	0	0	0	0	0	0	0	7	9	0	0	0	1	0	0	17	0.04
19.6 - 20.0	0	0	0	0	0	0	0	0	5	3	0	1	0	0	0	0	9	0.02
20.0 - 20.4	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	5	0.01
20.4 - 20.8	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	5	0.01
20.8 - 21.2	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	2	0.00
21.2 - 21.6	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	4	0.01
21.6 - 22.0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
22.0 - 22.4	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0.00
22.4 - 22.8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
22.8 - 23.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
23.2 - 23.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
23.6 - 24.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.0 - 24.4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0.00
24.4 - 24.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.8 - 25.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25.2 - 25.6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.00
25.6 - 26.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.0 - 26.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.4 - 26.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.8 - 27.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.2 - 27.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.6 - 28.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00

TABLE B-7 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SUMMER - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
28.0 / 28.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.4 / 28.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.8 / 29.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.2 / 29.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.6 / 30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.0 / 30.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.4 / 30.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.8 / 31.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.2 / 31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6 / 32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0 / 32.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.4 / 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 / 33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2 / 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 / 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 / 34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 / 34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 / 35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 / 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 / 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 / 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 / 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 / 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 / 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 / 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 / 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 / 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 / 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 / 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 / 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	1494	1291	1984	3945	3926	1707	947	796	4012	6004	4709	4938	4098	1742	1057	1156	43806	100.00
PERCENT FREQ	3.41	2.95	4.53	9.01	8.96	3.90	2.16	1.82	9.16	13.71	10.75	11.27	9.35	3.98	2.41	2.64	100.00	
AVERAGE WIND SPEED (M/S)	3.4	3.0	4.2	5.4	5.7	4.6	3.6	3.3	9.4	7.8	5.7	6.1	6.2	4.6	3.3	4.0		

TABLE B-7 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

FALL – 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
0.0 / 0.4	0	0	0	0	1	0	0	0	6	3	0	0	0	0	0	0	10	0.02
0.4 / 0.8	0	1	0	0	2	0	0	0	4	0	0	0	0	2	1	1	11	0.02
0.8 / 1.2	0	1	0	1	1	0	0	1	3	0	0	1	0	2	1	1	11	0.02
1.2 / 1.6	23	31	53	34	71	59	45	41	66	41	51	43	43	41	32	25	699	1.26
1.6 / 2.0	273	289	380	316	392	241	217	200	233	225	323	315	279	276	290	260	4509	8.13
2.0 / 2.4	183	176	204	184	243	111	72	84	98	139	183	144	150	127	154	156	2408	4.34
2.4 / 2.8	189	159	131	161	240	118	55	90	86	97	116	147	118	114	97	123	2041	3.68
2.8 / 3.2	150	132	128	177	196	95	34	59	70	101	143	128	146	135	93	115	1902	3.43
3.2 / 3.6	148	96	122	179	177	59	33	24	65	128	148	130	134	134	99	80	1767	3.19
3.6 / 4.0	98	77	122	173	204	52	26	30	50	93	146	190	173	87	89	94	1704	3.07
4.0 / 4.4	89	53	81	186	217	54	20	16	51	114	155	209	163	92	85	71	1656	2.99
4.4 / 4.8	51	28	88	207	300	57	17	11	43	115	173	238	191	84	64	70	1737	3.13
4.8 / 5.2	52	20	82	220	334	54	9	12	44	83	177	279	191	74	51	68	1750	3.16
5.2 / 5.6	44	13	55	251	356	31	8	11	34	97	213	356	194	50	35	50	1825	3.29
5.6 / 6.0	46	14	41	294	332	33	5	6	42	93	209	384	193	54	29	36	1825	3.29
6.0 / 6.4	34	12	30	302	342	21	5	6	53	112	237	377	217	33	34	43	1853	3.34
6.4 / 6.8	30	11	38	287	358	18	0	3	49	125	248	405	239	34	23	37	1881	3.39
6.8 / 7.2	35	16	23	266	383	20	0	2	48	121	227	428	231	27	22	40	1879	3.39
7.2 / 7.6	22	8	34	283	372	16	3	1	60	132	291	369	227	20	16	29	1854	3.34
7.6 / 8.0	11	0	21	329	364	9	3	2	57	145	251	382	206	21	12	33	1920	3.46
8.0 / 8.4	19	0	20	366	303	10	2	2	56	138	256	372	196	25	6	42	1880	3.39
8.4 / 8.8	14	0	6	371	304	14	1	2	43	187	248	309	225	32	7	36	1791	3.23
8.8 / 9.2	9	0	5	346	221	5	1	2	49	201	247	270	221	20	6	26	1718	3.10
9.2 / 9.6	9	0	3	328	213	3	0	2	69	194	246	251	225	22	3	21	1595	2.88
9.6 / 10.0	14	0	0	260	206	8	0	0	79	175	235	235	225	19	4	22	1503	2.71
10.0 / 10.4	7	0	0	270	219	8	0	0	81	197	190	213	200	20	4	11	1453	2.62
10.4 / 10.8	3	0	1	221	194	4	0	0	80	231	206	218	181	23	3	13	1386	2.50
10.8 / 11.2	0	0	1	199	189	4	0	0	81	217	177	193	170	31	0	15	1311	2.36
11.2 / 11.6	1	0	0	183	186	0	0	0	71	263	148	161	152	12	2	4	1216	2.19
11.6 / 12.0	0	0	5	169	180	0	0	0	84	216	154	126	143	14	0	6	1092	1.97
12.0 / 12.4	4	0	5	131	162	0	0	0	89	215	135	111	144	15	0	6	1054	1.90
12.4 / 12.8	1	0	5	92	128	0	0	0	93	222	110	111	112	9	0	8	950	1.71
12.8 / 13.2	0	0	1	78	89	0	0	0	64	226	110	79	73	14	0	2	779	1.40
13.2 / 13.6	0	0	1	66	74	0	0	0	60	221	104	48	64	16	1	2	672	1.21
13.6 / 14.0	0	0	0	32	74	0	0	0	59	157	104	37	51	13	0	1	528	0.95

TABLE B-8

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

FALL - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
14.0 14.4	0	0	0	20	41	0	0	0	51	167	94	28	39	3	0	6	449	0.81
14.4 14.8	1	0	0	13	29	0	0	0	55	139	91	15	11	8	0	2	364	0.66
14.8 15.2	0	0	0	6	30	0	0	0	80	106	74	18	7	3	0	0	324	0.58
15.2 15.6	0	0	0	5	32	0	0	0	66	90	72	11	11	3	0	3	293	0.53
15.6 16.0	0	0	0	1	24	0	0	0	49	117	71	7	7	3	0	1	280	0.50
16.0 16.4	0	0	0	2	20	0	0	0	28	131	51	7	7	1	0	1	240	0.43
16.4 16.8	0	0	0	1	16	0	0	1	39	111	61	3	3	1	0	2	234	0.42
16.8 17.2	0	0	0	0	19	0	0	0	41	88	42	0	2	0	0	2	196	0.35
17.2 17.6	0	0	0	2	12	0	0	0	30	90	40	2	2	0	0	1	173	0.31
17.6 18.0	0	0	0	0	7	0	0	0	18	61	34	1	1	0	0	3	127	0.23
18.0 18.4	0	0	0	0	14	0	0	0	7	56	22	0	1	0	0	1	100	0.18
18.4 18.8	0	0	0	0	8	0	0	0	16	46	14	1	0	0	0	0	84	0.15
18.8 19.2	0	0	0	0	9	0	0	0	15	38	15	0	0	0	0	0	77	0.14
19.2 19.6	0	0	0	0	3	0	0	0	12	24	6	0	0	0	0	1	46	0.08
19.6 20.0	0	0	0	0	1	0	0	0	19	23	3	0	0	0	0	0	49	0.09
20.0 20.4	0	0	0	0	2	0	0	0	14	7	6	0	0	0	0	0	26	0.05
20.4 20.8	0	0	0	0	0	0	0	0	12	4	3	0	0	0	0	0	19	0.03
20.8 21.2	0	1	0	0	0	0	0	0	15	1	3	0	0	0	0	0	20	0.04
21.2 21.6	0	0	0	0	0	0	0	0	18	2	1	1	0	0	0	0	22	0.04
21.6 22.0	0	0	0	0	0	0	0	0	12	2	1	0	0	0	0	0	15	0.03
22.0 22.4	0	0	0	0	0	0	0	0	16	1	0	0	0	0	0	0	17	0.03
22.4 22.8	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	11	0.02
22.8 23.2	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	13	0.02
23.2 23.6	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	15	0.03
23.6 24.0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	20	0.04
24.0 24.4	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	14	0.03
24.4 24.8	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	11	0.02
24.8 25.2	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	9	0.02
25.2 25.6	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	10	0.02
25.6 26.0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	8	0.01
26.0 26.4	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0.00
26.4 26.8	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4	0.01
26.8 27.2	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0.01
27.2 27.6	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4	0.01
27.6 28.0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.00

TABLE B-8 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

FALL - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S)	>= 348 < 11	11 33	33 56	56 78	78 101	101 123	123 146	146 168	168 191	191 213	213 236	236 258	258 281	281 303	303 326	326 348	TOTAL FREQ	PERCENT FREQ
28.0 - 28.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.4 - 28.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.8 - 29.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.2 - 29.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.6 - 30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.0 - 30.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.4 - 30.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.8 - 31.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.2 - 31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6 - 32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0 - 32.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.4 - 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 - 33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2 - 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 - 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 - 34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 - 34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 - 35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 - 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 - 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 - 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 - 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 - 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 - 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 - 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 - 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 - 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 - 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 - 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 - 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	1561	1137	1767	7012	8146	1104	557	606	2958	6328	6817	7332	5579	1712	1264	1570	55450	100.00
PERCENT FREQ	2.82	2.05	3.19	12.65	14.69	1.99	1.00	1.09	5.33	11.41	12.29	13.22	10.06	3.09	2.28	2.83	100.00	
AVERAGE WIND SPEED (M/S)	2.7	2.9	3.7	7.4	7.4	6.6	2.7	2.7	10.0	10.1	8.4	7.2	7.4	4.8	3.5	4.6		

TABLE B-8 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

WINTER - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
0.0 / 0.4	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	21	0.15
0.4 / 0.8	0	0	0	0	0	0	0	0	7	1	0	0	0	0	0	0	8	0.06
0.8 / 1.2	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	16	0.11
1.2 / 1.6	1	2	5	11	11	18	10	10	14	1	4	7	1	1	2	17	38	0.27
1.6 / 2.0	33	14	9	7	4	3	5	5	27	28	15	17	32	33	16	20	312	2.23
2.0 / 2.4	17	7	3	0	2	4	1	1	13	3	8	11	30	32	24	8	189	1.35
2.4 / 2.8	7	9	0	0	0	1	3	2	4	3	7	11	28	34	29	12	144	1.03
2.8 / 3.2	10	9	1	0	0	0	0	1	7	3	3	14	30	22	14	11	150	1.07
3.2 / 3.6	2	4	0	0	0	1	0	0	3	5	8	11	23	15	18	13	127	0.91
3.6 / 4.0	3	0	0	0	0	0	0	0	1	3	8	16	26	5	21	7	97	0.69
4.0 / 4.4	4	1	0	0	0	0	0	0	2	0	7	18	11	11	16	9	88	0.63
4.4 / 4.8	2	0	0	0	0	0	0	0	2	4	5	26	15	11	14	11	91	0.65
4.8 / 5.2	3	1	0	0	0	0	0	0	2	4	10	19	14	5	0	9	92	0.66
5.2 / 5.6	3	0	0	0	0	0	0	0	0	3	16	23	25	2	8	7	87	0.62
5.6 / 6.0	0	0	0	0	0	0	0	0	1	4	10	36	21	5	8	13	93	0.67
6.0 / 6.4	2	0	0	0	0	0	0	0	1	6	25	44	16	3	14	6	125	0.89
6.4 / 6.8	2	0	0	0	0	0	0	0	0	14	36	75	15	0	4	8	166	1.19
6.8 / 7.2	0	0	0	0	0	0	0	0	0	19	44	98	18	0	3	6	192	1.37
7.2 / 7.6	1	0	0	0	0	0	0	0	0	24	64	122	19	0	2	14	237	1.70
7.6 / 8.0	1	0	0	0	0	0	0	0	2	37	68	137	18	0	5	11	279	2.00
8.0 / 8.4	1	0	0	0	0	0	0	0	4	47	87	135	14	0	7	20	308	2.21
8.4 / 8.8	4	0	0	0	0	0	0	0	8	64	120	165	11	0	3	22	399	2.86
8.8 / 9.2	0	0	0	0	0	0	0	0	5	87	131	178	6	0	1	23	438	3.14
9.2 / 9.6	0	0	0	0	0	0	0	0	7	94	134	175	6	0	4	29	444	3.18
9.6 / 10.0	0	0	0	0	0	0	0	0	10	97	147	164	6	0	1	14	457	3.27
10.0 / 10.4	0	0	0	0	0	0	0	0	10	102	194	158	7	0	3	25	485	3.47
10.4 / 10.8	0	0	0	0	0	0	0	0	7	81	165	179	6	0	1	12	467	3.34
10.8 / 11.2	0	0	0	0	0	0	0	0	7	107	152	140	6	0	0	8	425	3.04
11.2 / 11.6	0	0	0	0	0	0	0	0	2	92	146	117	7	0	0	4	386	2.76
11.6 / 12.0	0	0	0	0	0	0	0	0	4	151	146	58	7	0	0	3	427	3.06
12.0 / 12.4	0	0	0	0	0	0	0	0	6	156	123	42	1	0	0	0	353	2.53
12.4 / 12.8	0	0	0	0	0	0	0	0	0	166	118	46	3	0	0	1	337	2.41
12.8 / 13.2	0	0	0	0	0	0	0	0	6	201	85	24	5	0	0	0	342	2.45
13.2 / 13.6	0	0	0	0	0	0	0	0	18	208	90	29	5	0	0	0	345	2.47
13.6 / 14.0	0	0	0	0	0	0	0	0	27	191	70	5	0	0	0	0	322	2.31

TABLE B-9

WINTER - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<=	346 11	11 33	33 56	56 78	78 101	101 123	123 146	146 168	168 191	191 213	213 236	236 258	258 281	281 303	303 326	326 348	TOTAL FREQ	PERCENT FREQ
14.0	14.4	0	0	0	0	0	0	0	0	30	191	71	20	0	0	0	0	312	2.23
14.4	14.8	0	0	0	0	0	0	0	0	28	209	55	21	2	0	0	0	315	2.26
14.8	15.2	0	0	0	0	0	0	0	0	44	239	35	13	1	0	0	0	332	2.38
15.2	15.6	0	0	0	0	0	0	0	0	48	204	46	12	0	0	0	0	310	2.22
15.6	16.0	0	0	0	0	0	0	0	0	61	205	36	7	1	0	0	0	310	2.22
16.0	16.4	0	0	0	0	0	0	0	0	79	195	30	9	0	0	0	0	313	2.24
16.4	16.8	0	0	0	0	0	0	0	0	68	150	31	3	0	0	0	0	252	1.80
16.8	17.2	0	0	0	0	0	0	0	0	81	162	22	5	0	0	0	0	270	1.93
17.2	17.6	0	0	0	0	0	0	0	0	103	142	5	3	0	0	0	0	253	1.81
17.6	18.0	0	0	0	0	0	0	0	0	97	113	5	0	0	0	0	0	215	1.54
18.0	18.4	0	0	0	0	0	0	0	0	103	112	10	1	0	0	0	0	226	1.62
18.4	18.8	0	0	0	0	0	0	0	0	117	87	6	1	0	0	0	0	211	1.51
18.8	19.2	0	0	0	0	0	0	0	0	142	100	1	1	0	0	0	0	248	1.78
19.2	19.6	0	0	0	0	0	0	0	0	116	80	1	0	0	0	0	0	198	1.42
19.6	20.0	0	0	0	0	0	0	0	0	118	73	7	1	0	0	0	0	200	1.43
20.0	20.4	0	0	0	0	0	0	0	0	154	70	1	0	0	0	0	0	225	1.61
20.4	20.8	0	0	0	0	0	0	0	0	125	62	5	0	0	0	0	0	192	1.37
20.8	21.2	0	0	0	0	0	0	0	0	128	38	1	0	0	0	0	0	167	1.20
21.2	21.6	0	0	0	0	0	0	0	0	93	36	1	0	0	0	0	0	130	0.93
21.6	22.0	0	0	0	0	0	0	0	0	104	32	1	0	0	0	0	0	137	0.98
22.0	22.4	0	0	0	0	0	0	0	0	81	20	1	0	0	0	0	0	102	0.73
22.4	22.8	0	0	0	0	0	0	0	0	84	15	0	0	0	0	0	0	99	0.71
22.8	23.2	0	0	0	0	0	0	0	0	62	14	1	0	0	0	0	0	77	0.55
23.2	23.6	0	0	0	0	0	0	0	0	52	9	0	0	0	0	0	0	61	0.44
23.6	24.0	0	0	0	0	0	0	0	0	29	12	1	0	0	0	0	0	42	0.30
24.0	24.4	0	0	0	0	0	0	0	0	42	9	0	0	0	0	0	0	51	0.37
24.4	24.8	0	0	0	0	0	0	0	0	39	3	0	0	0	0	0	0	42	0.30
24.8	25.2	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	36	0.27
25.2	25.6	0	0	0	0	0	0	0	0	25	1	0	0	0	0	0	0	25	0.18
25.6	26.0	0	0	0	0	0	0	0	0	27	0	0	0	0	0	0	0	28	0.20
26.0	26.4	0	0	0	0	0	0	0	0	21	1	0	0	0	0	0	0	21	0.15
26.4	26.8	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	8	0.06
26.8	27.2	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	16	0.11
27.2	27.6	0	0	0	0	0	0	0	0	13	1	0	0	0	0	0	0	14	0.10
27.6	28.0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	9	0.06

TABLE B-9 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

WINTER - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
28.0 – 28.4	0	0	0	0	0	0	0	0	8	1	0	0	0	0	0	0	9	0.06
28.4 – 28.8	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0.02
28.8 – 29.2	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	5	0.04
29.2 – 29.6	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0.02
29.6 – 30.0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.01
30.0 – 30.4	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0.01
30.4 – 30.8	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	4	0.03
30.8 – 31.2	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	3	0.02
31.2 – 31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6 – 32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0 – 32.4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.01
32.4 – 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 – 33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2 – 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 – 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 – 34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 – 34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 – 35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 – 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 – 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 – 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 – 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 – 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 – 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 – 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 – 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 – 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 – 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 – 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 – 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	98	47	18	18	17	27	18	20	2654	4606	2639	2508	469	216	269	343	13967	100.00
PERCENT FREQ	0.70	0.34	0.13	0.13	0.12	0.19	0.13	0.14	19.00	32.98	18.89	17.96	3.36	1.55	1.93	2.46	100.00	
AVERAGE WIND SPEED (M/S)	3.8	6.5	1.8	1.9	1.9	2.1	2.1	2.1	19.4	14.5	11.0	9.4	5.8	3.2	4.4	7.1		

TABLE B-9 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

ANNUAL - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) > / =<	>=348 <11	>=11 <33	>=33 <56	>=56 <78	>=78 <101	>=101 <123	>=123 <146	>=146 <168	>=168 <191	>=191 <213	>=213 <236	>=236 <258	>=258 <281	>=281 <303	>=303 <326	>=326 <348	TOTAL FREQ	PERCENT FREQ
0.0 / 0.4	0	0	0	0	1	0	0	0	28	3	0	0	0	0	0	0	32	0.02
0.4 / 0.8	0	2	1	0	2	1	0	0	11	1	0	0	0	2	1	1	21	0.01
0.8 / 1.2	0	1	0	2	1	1	0	1	19	0	0	0	1	0	2	1	29	0.02
1.2 / 1.6	52	72	83	92	129	74	63	72	98	67	86	67	59	61	54	41	1170	0.82
1.6 / 2.0	827	842	1027	903	980	609	529	543	650	700	785	787	762	691	776	712	12123	8.50
2.0 / 2.4	511	485	573	637	676	368	270	266	314	376	556	437	473	432	427	403	7204	5.05
2.4 / 2.8	421	364	398	592	574	304	167	214	236	335	431	440	400	325	278	317	5796	4.07
2.8 / 3.2	339	328	370	524	496	264	135	148	233	306	306	399	361	361	255	253	5203	3.65
3.2 / 3.6	295	257	314	414	399	187	111	96	175	326	400	453	402	295	259	214	4597	3.22
3.6 / 4.0	245	201	278	377	421	159	95	74	151	312	419	509	411	232	219	217	4319	3.03
4.0 / 4.4	241	178	234	403	384	179	98	63	156	338	497	543	404	233	180	157	4288	3.01
4.4 / 4.8	157	117	252	414	468	185	70	41	125	330	529	695	409	206	142	152	4292	3.01
4.8 / 5.2	132	90	247	411	527	193	48	28	130	293	603	723	406	174	140	141	4286	3.01
5.2 / 5.6	104	53	220	465	537	196	50	28	118	306	641	816	439	136	92	117	4305	3.02
5.6 / 6.0	109	41	152	534	539	183	38	23	121	320	632	843	435	141	62	103	4289	3.01
6.0 / 6.4	90	36	103	586	623	196	31	21	136	384	697	900	504	126	70	113	4562	3.20
6.4 / 6.8	92	30	103	590	669	142	41	8	150	462	690	933	548	131	62	103	4741	3.33
6.8 / 7.2	79	31	97	562	643	129	16	10	164	462	650	971	530	104	38	99	4562	3.20
7.2 / 7.6	71	17	78	543	635	106	20	8	182	529	736	918	566	111	33	88	4649	3.26
7.6 / 8.0	53	11	86	565	659	114	14	11	186	570	732	999	562	95	26	97	4757	3.34
8.0 / 8.4	51	5	80	589	658	91	10	6	189	606	714	970	567	114	28	86	4739	3.32
8.4 / 8.8	35	0	72	621	557	66	17	7	193	682	761	858	536	102	23	94	4616	3.24
8.8 / 9.2	21	5	59	616	571	58	7	7	197	716	695	837	530	84	19	96	4508	3.16
9.2 / 9.6	24	1	36	574	396	47	5	10	238	656	651	775	467	49	9	80	4006	2.81
9.6 / 10.0	21	1	32	520	300	35	4	5	238	667	603	709	475	61	13	95	3774	2.65
10.0 / 10.4	12	0	21	475	276	30	1	5	294	659	603	662	437	43	9	50	3572	2.51
10.4 / 10.8	8	0	20	407	311	25	3	4	288	624	498	673	387	46	10	75	3364	2.36
10.8 / 11.2	0	0	13	317	244	10	1	0	296	622	499	585	359	48	6	58	3054	2.14
11.2 / 11.6	4	0	11	304	244	6	0	0	284	636	440	497	310	29	4	37	2800	1.96
11.6 / 12.0	4	0	9	262	229	0	0	3	289	596	388	437	271	25	2	31	2547	1.79
12.0 / 12.4	4	0	11	227	208	1	2	0	271	549	362	327	284	24	2	38	2309	1.62
12.4 / 12.8	2	0	9	175	191	0	0	0	318	548	329	281	202	16	1	37	2109	1.48
12.8 / 13.2	0	0	11	146	157	0	0	0	264	571	247	227	153	21	3	20	1820	1.28
13.2 / 13.6	0	0	9	122	99	0	0	0	245	553	255	158	143	23	2	31	1641	1.15
13.6 / 14.0	0	0	3	74	90	0	0	1	245	457	218	145	113	18	0	17	1381	0.97

TABLE B-10

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

ANNUAL - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S)	>=348 <11	>=11 <33	>=33 <56	>=56 <78	>=78 <101	>=101 <123	>=123 <146	>=146 <168	>=168 <191	>=191 <213	>=213 <236	>=236 <258	>=258 <281	>=281 <303	>=303 <326	>=326 <348	TOTAL FREQ	PERCENT FREQ
14.0 – 14.4	0	0	1	47	49	0	1	0	234	458	197	108	77	4	1	16	1193	0.84
14.4 – 14.8	1	0	3	20	41	0	0	0	206	426	175	78	34	1	0	11	1006	0.71
14.8 – 15.2	1	0	0	15	30	0	0	0	225	434	124	45	37	4	0	10	924	0.65
15.2 – 15.6	0	0	0	9	33	0	0	0	195	365	131	46	26	5	0	8	818	0.57
15.6 – 16.0	0	0	0	2	24	0	0	1	187	381	117	31	18	2	0	3	769	0.54
16.0 – 16.4	0	0	0	2	21	0	0	0	147	393	88	20	12	1	0	2	687	0.48
16.4 – 16.8	0	0	0	1	16	0	0	2	144	310	103	12	6	1	0	2	597	0.42
16.8 – 17.2	0	0	0	0	19	0	0	0	153	303	71	13	3	1	0	1	565	0.40
17.2 – 17.6	0	0	0	0	12	0	0	1	161	290	49	6	2	0	0	3	522	0.37
17.6 – 18.0	0	0	0	2	7	0	0	0	130	207	41	5	3	0	0	1	399	0.28
18.0 – 18.4	0	0	0	0	14	0	0	0	124	215	35	3	0	0	0	0	392	0.27
18.4 – 18.8	0	0	0	0	8	0	0	0	142	169	20	3	2	0	0	1	344	0.24
18.8 – 19.2	0	0	0	0	9	0	0	0	163	180	22	1	1	1	0	0	376	0.26
19.2 – 19.6	0	0	0	0	3	0	0	0	135	149	8	1	0	0	0	1	298	0.21
19.6 – 20.0	0	0	0	0	1	0	0	0	143	127	13	3	0	1	0	0	287	0.20
20.0 – 20.4	1	0	0	0	2	0	0	0	173	109	4	0	0	0	0	1	288	0.20
20.4 – 20.8	0	0	0	0	0	0	0	0	141	87	8	0	0	0	0	0	236	0.17
20.8 – 21.2	1	0	0	0	0	0	0	0	144	64	4	1	0	0	0	0	214	0.15
21.2 – 21.6	0	0	0	0	0	0	0	0	115	55	4	1	1	0	0	0	173	0.12
21.6 – 22.0	0	0	0	0	0	0	0	0	117	49	2	0	0	0	0	0	168	0.12
22.0 – 22.4	0	0	0	0	0	0	0	0	102	34	1	0	0	0	0	0	137	0.10
22.4 – 22.8	0	0	0	0	0	0	0	0	95	29	0	1	0	0	0	0	125	0.09
22.8 – 23.2	0	0	0	0	0	0	0	0	75	21	1	0	0	0	0	0	97	0.07
23.2 – 23.6	0	0	0	0	0	0	0	0	67	12	0	0	0	0	0	0	79	0.06
23.6 – 24.0	0	0	0	0	0	0	0	0	49	12	1	0	0	0	0	0	62	0.04
24.0 – 24.4	0	0	0	0	0	0	0	0	57	10	0	0	0	0	0	0	67	0.05
24.4 – 24.8	0	0	0	0	0	0	0	0	50	3	0	0	0	0	0	0	53	0.04
24.8 – 25.2	0	0	0	0	0	0	0	0	38	9	0	0	0	0	0	0	47	0.03
25.2 – 25.6	0	0	0	0	0	0	0	0	35	0	0	0	0	0	0	0	35	0.02
25.6 – 26.0	0	0	0	0	0	0	0	0	35	1	0	0	0	0	0	0	36	0.03
26.0 – 26.4	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	24	0.02
26.4 – 26.8	0	0	0	0	0	0	0	0	11	1	0	0	0	0	0	0	12	0.02
26.8 – 27.2	0	0	0	0	0	0	0	0	19	0	0	0	0	0	0	0	19	0.01
27.2 – 27.6	0	0	0	0	0	0	0	0	17	1	0	0	0	0	0	0	18	0.01
27.6 – 28.0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	10	0.01

TABLE B-10 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

ANNUAL - 30 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S)	>= 348 < 11	>= 11 < 33	>= 33 < 56	>= 56 < 78	>= 78 < 101	>= 101 < 123	>= 123 < 146	>= 146 < 168	>= 168 < 191	>= 191 < 213	>= 213 < 236	>= 236 < 258	>= 258 < 281	>= 281 < 303	>= 303 < 326	>= 326 < 348	TOTAL FREQ	PERCENT FREQ
28.0 – 28.4	0	0	0	0	0	0	0	0	8	1	0	0	0	0	0	0	9	0.01
28.4 – 28.8	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0.00
28.8 – 29.2	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	0	5	0.00
29.2 – 29.6	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3	0.00
29.6 – 30.0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.00
30.0 – 30.4	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0.00
30.4 – 30.8	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	4	0.00
30.8 – 31.2	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	3	0.00
31.2 – 31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6 – 32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0 – 32.4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
32.4 – 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 – 33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2 – 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 – 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 – 34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 – 34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 – 35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 – 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 – 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 – 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 – 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 – 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 – 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 – 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 – 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 – 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 – 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 – 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 – 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	4006	3168	5016	14141	14183	3762	1847	1708	11121	20472	17960	19951	13162	4594	3248	4234	142573	
PERCENT FREQ	2.81	2.22	3.52	9.92	9.95	2.64	1.30	1.20	7.80	14.36	12.60	13.99	9.23	3.22	2.28	2.97		100.00
AVERAGE WIND SPEED (M/S)	3.6	3.0	4.0	6.9	6.7	4.3	3.2	3.0	11.8	10.4	7.9	7.4	7.2	4.8	3.5	5.1		

TABLE B-10 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SPRING - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
0.0 – 0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
0.4 – 0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
0.8 – 1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
1.2 – 1.6	150	186	290	235	188	80	63	84	108	127	131	116	129	113	126	127	2253	7.64
1.6 – 2.0	97	139	162	182	128	66	37	53	59	109	134	106	117	98	86	95	1668	5.66
2.0 – 2.4	71	69	105	116	89	55	23	40	52	71	73	83	63	59	59	78	1142	3.87
2.4 – 2.8	45	61	108	93	80	56	27	55	34	88	62	90	65	57	32	49	986	3.35
2.8 – 3.2	37	39	53	80	61	40	24	18	55	62	82	101	76	53	52	49	834	2.83
3.2 – 3.6	46	24	44	71	71	36	14	34	27	62	66	94	55	56	56	33	718	2.44
3.6 – 4.0	51	18	35	44	44	49	10	27	25	42	78	74	55	40	35	34	707	2.40
4.0 – 4.4	33	20	38	57	71	37	6	25	42	51	66	89	74	44	28	33	811	2.75
4.4 – 4.8	19	30	47	56	44	46	11	26	51	37	109	68	30	30	29	26	806	2.73
4.8 – 5.2	24	23	61	57	87	38	5	24	37	35	131	59	42	16	16	21	836	2.84
5.2 – 5.6	30	20	33	48	80	42	9	28	35	131	144	74	39	6	29	21	818	2.78
5.6 – 6.0	22	18	14	57	80	32	8	22	49	144	176	83	24	4	6	16	801	2.72
6.0 – 6.4	34	13	17	69	94	48	6	22	59	140	195	81	19	7	4	19	914	3.10
6.4 – 6.8	38	16	13	77	127	52	13	22	92	140	202	103	34	4	7	25	943	3.20
6.8 – 7.2	30	7	15	63	120	46	4	18	97	147	202	123	35	9	5	31	1002	3.40
7.2 – 7.6	25	6	11	89	112	45	2	25	103	179	200	138	33	5	8	42	1054	3.58
7.6 – 8.0	17	11	13	94	119	23	1	21	120	182	206	141	30	8	2	25	971	3.29
8.0 – 8.4	17	13	17	86	91	4	3	21	112	159	241	135	37	2	6	26	1078	3.66
8.4 – 8.8	17	17	15	98	117	3	0	22	134	193	271	163	29	4	2	31	1085	3.68
8.8 – 9.2	14	15	8	114	114	1	3	21	130	195	235	122	17	6	4	35	930	3.16
9.2 – 9.6	4	2	8	129	75	0	1	32	121	130	231	131	12	2	6	34	942	3.20
9.6 – 10.0	5	1	9	145	61	1	0	46	122	138	220	143	15	1	2	31	872	2.96
10.0 – 10.4	4	0	7	149	36	0	0	45	133	103	212	131	12	1	1	18	841	2.85
10.4 – 10.8	1	0	10	154	33	0	0	44	107	117	210	135	11	1	0	28	759	2.58
10.8 – 11.2	3	0	5	103	27	0	0	51	107	88	197	136	14	0	1	23	677	2.30
11.2 – 11.6	0	0	5	98	25	0	0	49	89	70	196	115	16	1	2	25	598	2.03
11.6 – 12.0	0	0	4	90	21	0	0	50	72	77	146	101	10	0	0	21	601	2.04
12.0 – 12.4	0	0	4	99	16	0	0	60	66	59	162	105	9	2	0	20	579	1.96
12.4 – 12.8	0	0	4	86	21	0	0	53	65	80	149	94	7	0	1	22	460	1.56
12.8 – 13.2	0	0	7	82	24	0	0	49	47	63	97	68	3	1	0	24	386	1.31
13.2 – 13.6	0	0	5	59	15	0	0	41	53	48	83	50	6	0	0	10	340	1.15
13.6 – 14.0	0	0	0	42	10	0	0	21	63	54	66	67	2	0	0	0		

TABLE B-11

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA

SPRING - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<	348/11	11/33	33/56	56/78	78/101	101/123	123/146	146/168	168/191	191/213	213/236	236/258	258/281	281/303	303/326	326/348	TOTAL FREQ	PERCENT FREQ
14.0	14.4	0	0	2	36	6	0	0	0	29	65	34	56	43	2	0	20	293	0.99
14.4	14.8	0	0	0	26	0	0	0	0	22	58	45	48	28	0	0	11	238	0.81
14.8	15.2	0	0	1	8	1	0	0	0	13	40	32	31	17	0	0	12	155	0.53
15.2	15.6	0	0	0	9	0	0	0	0	18	52	29	22	15	0	0	7	152	0.52
15.6	16.0	0	0	0	2	1	0	0	0	15	59	14	16	12	0	0	3	122	0.41
16.0	16.4	0	0	0	0	0	0	0	0	24	51	16	16	7	0	0	5	119	0.40
16.4	16.8	0	0	0	0	0	0	0	0	20	59	9	5	9	1	0	1	104	0.35
16.8	17.2	0	0	0	0	0	0	0	0	6	47	12	6	3	0	0	0	74	0.25
17.2	17.6	0	0	0	0	0	0	0	0	4	50	7	6	3	0	0	0	70	0.24
17.6	18.0	0	0	0	0	0	0	0	0	4	45	8	2	1	0	0	0	60	0.20
18.0	18.4	0	0	0	0	0	0	0	0	0	55	6	2	0	0	0	0	63	0.21
18.4	18.8	0	0	0	0	0	0	0	0	1	42	3	1	0	0	0	0	48	0.16
18.8	19.2	0	0	0	0	0	0	0	0	2	68	2	0	0	0	0	0	73	0.25
19.2	19.6	0	0	0	0	0	0	0	0	0	57	0	1	0	0	0	0	57	0.19
19.6	20.0	0	0	0	0	0	0	0	0	0	51	1	0	0	0	0	0	52	0.18
20.0	20.4	0	0	0	0	0	0	0	0	0	75	0	1	0	0	0	0	75	0.25
20.4	20.8	0	0	0	0	0	0	0	0	2	66	1	0	0	0	0	0	67	0.23
20.8	21.2	0	0	0	0	0	0	0	0	2	46	0	0	0	0	0	0	48	0.16
21.2	21.6	0	0	0	0	0	0	0	0	1	42	1	0	0	0	0	0	44	0.15
21.6	22.0	0	0	0	0	0	0	0	0	0	47	0	0	0	0	0	0	48	0.16
22.0	22.4	0	0	0	0	0	0	0	0	2	20	0	0	0	0	0	0	20	0.07
22.4	22.8	0	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	25	0.08
22.8	23.2	0	0	0	0	0	0	0	0	1	25	0	0	0	0	0	0	25	0.08
23.2	23.6	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	11	0.04
23.6	24.0	0	0	0	0	0	0	0	0	1	11	0	0	0	0	0	0	11	0.04
24.0	24.4	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0.01
24.4	24.8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
24.8	25.2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
25.2	25.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25.6	26.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.0	26.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.4	26.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.8	27.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.2	27.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.6	28.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00

TABLE B-11 (CONTINUED)

SPRING - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <=	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
28.0 28.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.4 28.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.8 29.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.2 29.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.6 30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.0 30.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.4 30.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.8 31.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.2 31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6 32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0 32.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.4 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	817	696	1166	3060	2230	799	252	267	1340	3794	3702	5396	3261	970	582	1139	29471	100.00
PERCENT FREQ	2.77	2.36	3.96	10.38	7.57	2.71	0.86	0.91	4.55	12.87	12.56	18.31	11.07	3.29	1.97	3.86	100.00	
AVERAGE WIND SPEED (M/S)	4.2	3.2	4.0	7.8	6.4	4.7	3.4	3.0	8.7	11.1	8.0	8.3	5.3	3.5	6.7			

TABLE B-11 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SUMMER - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<	348/11	11/33	33/56	56/78	78/101	101/123	123/146	146/168	168/191	191/213	213/236	236/258	258/281	281/303	303/326	326/348	TOTAL FREQ	PERCENT FREQ
0.0	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
0.4	0.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
0.8	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
1.2	1.6	222	236	233	232	204	157	109	121	143	182	211	260	251	211	179	181	3132	7.15
1.6	2.0	228	235	296	379	365	254	169	174	161	207	369	322	285	251	200	208	4103	9.37
2.0	2.4	169	155	158	277	297	143	94	94	107	147	276	254	201	133	105	111	2721	6.21
2.4	2.8	142	131	153	241	213	107	81	63	89	136	210	220	144	117	104	86	2237	5.11
2.8	3.2	99	102	133	140	176	73	46	46	97	146	234	185	100	87	87	74	1935	4.42
3.2	3.6	93	100	125	136	129	72	54	34	82	161	235	235	160	93	53	65	1790	4.09
3.6	4.0	86	103	94	156	121	96	55	36	70	141	214	214	148	86	35	42	1715	3.92
4.0	4.4	81	66	99	139	118	84	41	23	51	141	232	270	128	70	34	37	1610	3.68
4.4	4.8	56	37	72	151	125	87	22	11	49	133	252	301	142	55	43	34	1570	3.58
4.8	5.2	30	22	73	166	111	95	27	10	27	132	213	285	156	53	35	24	1459	3.33
5.2	5.6	39	11	51	171	145	90	21	8	39	172	224	271	136	49	16	28	1471	3.36
5.6	6.0	32	5	42	190	180	65	16	9	36	197	237	291	183	62	19	18	1582	3.61
6.0	6.4	25	5	36	213	221	63	18	8	58	222	240	300	213	67	18	39	1746	3.99
6.4	6.8	21	4	24	201	183	58	16	4	69	205	202	225	199	48	11	32	1502	3.43
6.8	7.2	21	4	29	178	203	59	8	8	72	246	228	228	179	61	6	24	1545	3.53
7.2	7.6	22	1	32	163	164	29	10	4	79	274	241	238	47	47	10	16	1522	3.47
7.6	8.0	15	0	23	150	190	34	9	8	69	293	193	221	219	54	14	16	1508	3.44
8.0	8.4	7	2	25	132	209	32	7	4	58	275	221	219	176	46	3	6	1352	3.09
8.4	8.8	5	5	14	126	163	31	9	3	65	287	187	176	167	37	3	10	1221	2.79
8.8	9.2	9	9	11	129	131	32	6	7	89	303	145	144	132	33	2	11	1170	2.67
9.2	9.6	1	1	5	85	99	29	3	3	79	253	94	102	18	18	0	3	906	2.07
9.6	10.0	5	5	7	67	70	15	3	1	121	252	74	91	15	15	3	5	801	1.83
10.0	10.4	6	6	4	39	72	14	3	3	113	258	82	74	10	10	3	3	737	1.68
10.4	10.8	2	2	3	32	58	9	1	3	102	248	57	64	7	7	6	6	646	1.47
10.8	11.2	4	4	4	20	31	2	2	0	105	184	59	52	7	7	1	7	504	1.15
11.2	11.6	3	3	2	8	32	1	1	0	130	209	66	36	4	1	0	1	516	1.18
11.6	12.0	0	0	2	6	21	0	0	1	132	156	36	30	6	6	1	4	410	0.94
12.0	12.4	2	0	2	2	19	0	0	0	104	130	26	28	4	4	4	2	332	0.76
12.4	12.8	1	0	0	0	9	0	0	2	127	132	20	22	5	5	3	5	330	0.75
12.8	13.2	0	0	0	0	7	0	0	0	132	119	14	15	5	5	0	6	306	0.70
13.2	13.6	0	0	0	0	2	0	0	0	123	89	6	11	20	2	1	2	256	0.58

TABLE B-12

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

SUMMER - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
14.0	14.4	1	0	0	0	5	0	0	0	114	62	1	10	12	3	0	2	210	0.48
14.4	14.8	1	0	0	0	8	0	0	0	89	53	1	7	9	0	1	3	172	0.39
14.8	15.2	0	0	0	0	0	0	1	0	105	51	3	9	4	2	0	1	176	0.40
15.2	15.6	0	0	0	0	0	0	0	0	79	38	0	2	5	1	0	1	126	0.29
15.6	16.0	0	0	0	0	0	0	0	0	70	19	1	2	2	1	0	0	95	0.22
16.0	16.4	0	0	0	0	0	0	0	0	48	14	0	5	0	2	0	0	69	0.16
16.4	16.8	0	0	0	0	0	0	0	1	42	13	1	1	1	2	0	0	61	0.14
16.8	17.2	0	0	0	0	0	0	0	0	28	4	0	4	0	0	0	0	36	0.08
17.2	17.6	0	0	0	0	0	0	0	0	28	8	0	1	1	0	0	0	38	0.09
17.6	18.0	0	0	0	0	0	0	0	1	24	10	0	1	0	0	0	0	36	0.08
18.0	18.4	0	0	0	0	0	0	0	1	23	13	0	0	1	0	0	0	38	0.09
18.4	18.8	0	0	0	0	0	0	0	0	6	8	0	2	1	1	0	0	19	0.04
18.8	19.2	0	0	0	0	0	0	0	0	12	4	0	1	2	0	0	0	19	0.04
19.2	19.6	0	0	0	0	0	0	0	0	4	3	0	0	2	0	0	0	9	0.02
19.6	20.0	0	0	0	0	0	0	0	0	5	3	0	1	0	0	0	0	9	0.02
20.0	20.4	0	0	0	0	0	0	0	0	2	9	0	0	1	0	0	0	12	0.03
20.4	20.8	0	0	0	0	0	0	0	0	6	7	0	0	0	0	0	0	13	0.03
20.8	21.2	0	0	0	0	0	0	0	0	4	4	0	1	0	0	0	0	9	0.02
21.2	21.6	0	0	0	0	0	0	0	0	2	5	0	0	0	0	0	0	7	0.02
21.6	22.0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	2	0.00
22.0	22.4	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0.00
22.4	22.8	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
22.8	23.2	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	3	0.01
23.2	23.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
23.6	24.0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.00
24.0	24.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.4	24.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
24.8	25.2	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0.00
25.2	25.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
25.6	26.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.0	26.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.4	26.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
26.8	27.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.2	27.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
27.6	28.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00

TABLE B-12 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA

SUMMER - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) > =<	>= 348 < 11	11 33	33 56	56 78	78 101	101 123	123 146	146 168	168 191	191 213	213 236	236 258	258 281	281 303	303 326	326 348	TOTAL FREQ	PERCENT FREQ
28.0 28.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.4 28.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
28.8 29.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.2 29.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
29.6 30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.0 30.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.4 30.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.8 31.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.2 31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6 32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0 32.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.4 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	1427	1219	1748	3929	4081	1730	829	690	3474	6355	4756	5426	4259	1770	994	1113	43800	100.00
PERCENT FREQ	3.26	2.78	3.99	8.97	9.32	3.95	1.89	1.58	7.93	14.51	10.86	12.39	9.72	4.04	2.27	2.54	100.00	
AVERAGE WIND SPEED (M/S)	3.7	3.1	3.9	5.5	5.9	4.6	3.7	3.4	9.7	8.3	5.8	6.0	6.4	4.8	3.5	4.0		

TABLE B-12 (CONTINUED)

FALL - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<	348 11	11 33	33 56	56 78	78 101	101 123	123 146	146 168	168 191	191 213	213 236	236 258	258 281	281 303	303 326	326 348	TOTAL FREQ	PERCENT FREQ
0.0	0.4	13	3	3	2	0	0	1	0	14	34	0	0	0	0	0	1	71	0.09
0.4	0.8	0	0	0	0	0	0	0	0	19	16	1	0	0	0	0	0	36	0.05
0.8	1.2	0	0	0	0	0	0	1	0	13	27	0	0	0	0	0	0	41	0.05
1.2	1.6	5	9	13	9	13	9	5	11	20	30	17	20	10	18	6	5	200	0.26
1.6	2.0	264	274	361	390	447	305	194	141	198	244	308	368	330	266	222	208	4520	5.87
2.0	2.4	348	355	408	376	433	285	165	133	181	197	357	357	333	253	278	294	4753	6.18
2.4	2.8	181	230	221	226	358	221	102	93	106	135	239	263	243	167	143	159	3087	4.01
2.8	3.2	193	148	136	212	276	175	51	52	76	117	194	223	210	140	109	91	2403	3.12
3.2	3.6	138	92	119	210	285	116	38	41	42	119	192	247	214	150	80	95	2178	2.83
3.6	4.0	107	64	80	179	254	95	41	26	40	80	177	224	232	109	74	82	1864	2.42
4.0	4.4	68	49	100	187	283	87	22	19	43	95	218	314	237	96	75	65	1967	2.56
4.4	4.8	77	30	94	272	396	44	17	14	33	106	240	333	239	92	73	68	2119	2.75
4.8	5.2	45	22	85	287	421	72	9	6	42	100	278	406	223	95	44	68	2203	2.86
5.2	5.6	44	17	90	261	430	65	5	2	43	80	325	459	236	83	40	57	2233	2.90
5.6	6.0	43		67	311	451	42	5	5	41	80	315	509	243	49	43	38	2286	2.97
6.0	6.4	41	8	52	324	457	20	2	3	48	91	320	532	246	52	40	35	2265	2.94
6.4	6.8	24	15	33	284	508	30	3	3	32	96	369	577	281	41	25	40	2372	3.08
6.8	7.2	31	32	32	282	520	34	3	1	26	111	373	584	293	35	28	28	2398	3.12
7.2	7.6	27	16	16	306	492	29	1	1	44	139	366	587	311	41	21	32	2418	3.14
7.6	8.0	19	12	26	377	522	23	0	4	66	152	388	586	332	35	12	24	2576	3.35
8.0	8.4	26	6	15	391	418	16	4	2	54	167	376	629	291	38	20	36	2458	3.19
8.4	8.8	18	0	0	382	401	7	2	1	55	189	349	570	290	19	5	24	2347	3.05
8.8	9.2	20	0	4	333	378	8	1	1	52	230	384	540	272	37	5	29	2282	2.97
9.2	9.6	23	1	0	348	329	11	1	4	35	235	405	538	273	27	9	20	2247	2.92
9.6	10.0	14	0	0	258	279	7	0	1	37	276	369	501	246	19	5	13	2049	2.66
10.0	10.4	5	0	0	244	288	6	1	2	34	310	296	418	234	34	9	12	1927	2.50
10.4	10.8	5	0	1	271	265	3	0	1	52	323	299	354	280	13	10	9	1869	2.43
10.8	11.2	3	0	0	265	237	1	0	0	66	364	284	314	262	18	7	12	1793	2.33
11.2	11.6	2	0	0	239	242	0	0	0	49	348	283	309	225	17	2	7	1631	2.12
11.6	12.0	0	0	0	224	242	0	0	0	70	382	238	264	195	25	1	6	1598	2.08
12.0	12.4	1	0	1	190	224	0	0	0	73	340	214	202	172	16	2	5	1416	1.84
12.4	12.8	1	1	1	166	212	0	0	0	76	388	225	173	146	20	1	5	1418	1.84
12.8	13.2	0	1	0	115	184	0	0	0	101	363	238	157	147	13	1	3	1323	1.72
13.2	13.6	0	0	0	80	142	0	0	0	102	346	177	107	144	16	0	5	1075	1.40
13.6	14.0	1	0	0	51	96	0	0	0	128	377	200	78	75	13	0	2	971	1.26

TABLE B-13

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

FALL - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<	348 11	11 33	33 56	56 78	78 101	101 123	123 146	146 168	168 191	191 213	213 236	236 258	258 281	281 303	303 326	326 348	TOTAL FREQ	PERCENT FREQ
14.0	14.4	3	0	0	38	67	0	0	0	107	343	169	69	67	12	0	1	876	1.14
14.4	14.8	1	0	0	19	37	0	0	0	150	277	136	40	45	12	0	3	720	0.94
14.8	15.2	0	0	0	14	36	0	0	0	124	268	141	35	37	12	0	4	671	0.87
15.2	15.6	0	0	0	11	30	0	0	0	115	224	126	27	27	3	0	2	565	0.73
15.6	16.0	3	0	0	0	27	0	0	0	86	225	92	16	24	5	0	0	487	0.63
16.0	16.4	0	0	0	9	15	0	0	0	77	201	83	19	18	2	0	3	424	0.55
16.4	16.8	0	0	0	6	19	0	0	0	76	242	86	4	12	1	0	0	444	0.58
16.8	17.2	0	0	0	4	10	0	0	0	80	245	76	4	6	0	0	2	425	0.55
17.2	17.6	0	0	0	2	10	0	0	0	81	221	53	4	2	0	0	1	373	0.48
17.6	18.0	2	0	0	1	13	0	0	0	55	228	68	7	1	0	0	3	373	0.48
18.0	18.4	1	0	0	1	8	0	0	0	55	215	65	4	1	0	0	0	354	0.46
18.4	18.8	0	0	0	1	11	0	0	0	37	172	44	7	1	0	0	2	272	0.35
18.8	19.2	0	0	0	0	8	0	0	0	30	195	57	4	1	0	0	0	292	0.38
19.2	19.6	0	0	0	1	5	0	0	0	32	175	39	1	0	0	0	2	254	0.33
19.6	20.0	0	0	0	0	5	0	0	0	28	136	31	0	0	0	0	0	200	0.26
20.0	20.4	0	0	0	0	0	0	0	0	32	181	32	0	0	0	0	1	246	0.32
20.4	20.8	0	0	0	0	1	0	0	0	24	147	25	0	0	0	0	0	197	0.26
20.8	21.2	0	0	0	0	0	0	0	0	18	119	17	0	0	0	0	0	154	0.20
21.2	21.6	0	0	0	0	0	0	0	0	16	98	12	0	0	0	0	0	126	0.16
21.6	22.0	1	0	0	0	0	0	0	0	15	91	7	0	0	0	0	0	114	0.15
22.0	22.4	0	0	0	0	0	0	0	0	8	68	9	0	0	0	0	0	85	0.11
22.4	22.8	0	0	0	0	0	0	0	0	14	85	7	0	1	0	0	0	107	0.14
22.8	23.2	0	0	0	0	0	0	0	0	8	83	0	0	0	0	0	0	91	0.12
23.2	23.6	0	0	0	0	0	0	0	0	13	79	2	0	0	0	0	0	94	0.12
23.6	24.0	0	0	0	0	0	0	0	0	18	69	1	0	0	0	0	0	88	0.11
24.0	24.4	0	0	0	0	0	0	0	0	16	58	2	0	0	0	0	0	76	0.10
24.4	24.8	0	0	0	0	0	0	0	0	22	78	0	0	0	0	0	0	100	0.13
24.8	25.2	0	0	0	0	0	0	0	0	26	51	0	0	0	0	0	0	77	0.10
25.2	25.6	0	0	0	0	0	0	0	0	26	38	0	0	0	0	0	0	64	0.08
25.6	26.0	0	0	0	0	0	0	0	0	18	28	0	0	0	0	0	0	46	0.06
26.0	26.4	0	0	0	0	0	0	0	0	14	34	0	0	0	0	0	0	48	0.06
26.4	26.8	0	0	0	0	0	0	0	0	19	15	0	0	0	0	0	0	34	0.04
26.8	27.2	0	0	0	0	0	0	0	0	12	27	0	0	0	0	0	0	39	0.05
27.2	27.6	0	0	0	0	0	0	0	0	6	11	0	0	0	0	0	0	17	0.02
27.6	28.0	0	0	0	0	0	0	0	0	7	9	0	0	0	0	0	0	16	0.02

TABLE B-13 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA

FALL - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / =<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
28.0 28.4	0	0	0	0	0	0	0	1	1	4	0	0	0	0	0	0	5	0.01
28.4 28.8	0	0	0	0	0	0	0	4	4	2	0	0	0	0	0	0	6	0.01
28.8 29.2	0	0	0	0	0	0	0	2	2	1	0	0	0	0	0	0	3	0.00
29.2 29.6	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2	0.00
29.6 30.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.0 30.4	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0.00
30.4 30.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
30.8 31.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.2 31.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
31.6 32.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.0 32.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.4 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 33.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.2 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	1828	1356	1968	8159	10765	1711	669	569	3583	11383	10326	11977	7568	2116	1360	1602	76960	100.00
PERCENT FREQ	2.38	1.76	2.56	10.60	13.99	2.22	0.87	0.74	4.66	14.79	13.42	15.56	9.83	2.75	1.79	2.08	100.00	
AVERAGE WIND SPEED (M/S)	3.9	2.8	3.4	7.4	7.3	3.5	2.7	2.8	11.7	13.0	8.9	7.6	7.5	5.0	3.7	4.5		

TABLE B-13 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

WINTER - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >= / <	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
0.0 / 0.4	0	0	0	0	0	0	0	0	26	14	0	0	0	0	0	0	40	0.28
0.4 / 0.8	0	0	0	0	0	0	0	0	27	10	0	0	0	0	0	0	37	0.26
0.8 / 1.2	0	0	0	0	0	0	0	0	11	5	0	0	0	0	0	0	16	0.11
1.2 / 1.6	0	0	0	0	0	0	0	0	12	6	1	1	0	0	0	0	20	0.14
1.6 / 2.0	12	15	15	15	4	12	7	9	26	15	21	20	27	25	26	26	275	1.95
2.0 / 2.4	18	7	3	4	3	2	7	3	19	10	5	8	21	22	23	17	172	1.22
2.4 / 2.8	15	11	1	1	3	3	1	2	8	13	5	6	26	31	15	10	150	1.07
2.8 / 3.2	6	11	1	0	0	1	1	1	10	7	9	8	46	32	21	14	167	1.19
3.2 / 3.6	7	3	0	0	0	1	0	0	4	2	8	12	31	21	27	8	123	0.87
3.6 / 4.0	6	1	0	0	0	0	0	0	3	6	8	11	26	15	17	12	105	0.75
4.0 / 4.4	2	2	0	0	0	0	0	0	3	4	4	10	17	5	14	15	84	0.60
4.4 / 4.8	3	3	0	0	0	1	1	1	2	3	6	24	15	10	15	7	83	0.59
4.8 / 5.2	5	1	0	0	0	0	0	0	1	1	7	27	15	6	16	12	99	0.70
5.2 / 5.6	3	1	0	0	0	0	0	0	1	3	10	19	16	6	12	15	77	0.55
5.6 / 6.0	3	0	0	0	0	0	0	0	1	1	7	29	22	2	2	13	82	0.58
6.0 / 6.4	2	0	0	0	0	0	0	0	2	4	17	32	23	1	9	9	97	0.69
6.4 / 6.8	2	0	0	0	0	0	0	0	0	11	24	50	21	0	9	13	126	0.90
6.8 / 7.2	3	0	0	0	0	0	0	0	0	15	36	84	42	1	1	9	180	1.28
7.2 / 7.6	1	0	0	0	0	0	0	0	0	17	30	99	18	1	0	11	181	1.29
7.6 / 8.0	0	0	0	0	0	0	0	0	1	20	54	125	25	0	1	11	253	1.80
8.0 / 8.4	2	0	0	0	0	0	0	0	0	23	63	159	23	0	0	10	276	1.96
8.4 / 8.8	0	0	0	0	0	0	0	0	0	45	71	169	15	0	2	13	323	2.30
8.8 / 9.2	3	0	0	0	0	0	0	0	1	55	84	186	10	0	0	13	372	2.64
9.2 / 9.6	2	0	0	0	0	0	0	0	3	67	102	207	5	0	0	18	424	3.01
9.6 / 10.0	2	0	0	0	0	0	0	0	2	85	114	211	17	0	0	28	451	3.20
10.0 / 10.4	3	0	0	0	0	0	0	0	4	73	124	215	18	0	0	26	453	3.22
10.4 / 10.8	5	0	0	0	0	0	0	0	2	68	138	229	13	0	0	27	474	3.37
10.8 / 11.2	1	0	0	0	0	0	0	0	1	55	119	213	13	0	0	19	433	3.08
11.2 / 11.6	6	0	0	0	0	0	0	0	3	62	119	163	15	0	0	21	374	2.66
11.6 / 12.0	0	0	0	0	0	0	0	0	0	94	140	153	12	0	0	14	408	2.90
12.0 / 12.4	0	0	0	0	0	0	0	0	0	99	138	141	9	0	0	8	398	2.83
12.4 / 12.8	0	0	0	0	0	0	0	0	0	119	126	101	6	0	0	5	361	2.57
12.8 / 13.2	0	0	0	0	0	0	0	0	1	130	104	92	6	0	0	3	330	2.35
13.2 / 13.6	0	0	0	0	0	0	0	0	1	132	92	52	0	0	0	0	284	2.02
13.6 / 14.0	0	0	0	0	0	0	0	0	1	176	123	29	0	0	0	1	335	2.38

TABLE B-14

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

WINTER - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >	=<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
14.0	14.4	0	0	0	0	0	0	0	0	2	170	84	29	6	0	0	0	291	2.07
14.4	14.8	0	0	0	0	0	0	0	0	1	160	84	35	1	0	0	0	281	2.00
14.8	15.2	0	0	0	0	0	0	0	0	3	186	69	24	2	0	0	0	284	2.02
15.2	15.6	0	0	0	0	0	0	0	0	4	217	55	20	6	0	0	0	302	2.15
15.6	16.0	0	0	0	0	0	0	0	0	2	221	53	20	4	0	0	0	300	2.13
16.0	16.4	0	0	0	0	0	0	0	0	7	212	53	10	4	0	0	0	286	2.03
16.4	16.8	0	0	0	0	0	0	0	0	13	224	53	9	3	0	0	0	302	2.15
16.8	17.2	0	0	0	0	0	0	0	0	15	221	32	10	1	0	0	0	279	1.98
17.2	17.6	0	0	0	0	0	0	0	0	18	212	33	6	0	0	0	0	269	1.91
17.6	18.0	0	0	0	0	0	0	0	0	23	225	27	4	0	0	0	0	279	1.98
18.0	18.4	0	0	0	0	0	0	0	0	17	203	19	0	0	0	0	0	239	1.70
18.4	18.8	0	0	0	0	0	0	0	0	29	177	9	5	0	0	0	0	220	1.56
18.8	19.2	0	0	0	0	0	0	0	0	25	192	10	1	0	0	0	0	228	1.62
19.2	19.6	0	0	0	0	0	0	0	0	41	165	11	2	0	0	0	0	203	1.44
19.6	20.0	0	0	0	0	0	0	0	0	38	178	8	1	0	0	0	0	217	1.61
20.0	20.4	0	0	0	0	0	0	0	0	32	159	6	1	0	0	0	0	210	1.49
20.4	20.8	0	0	0	0	0	0	0	0	45	146	4	1	0	0	0	0	196	1.39
20.8	21.2	0	0	0	0	0	0	0	0	52	131	7	0	0	0	0	0	198	1.41
21.2	21.6	0	0	0	0	0	0	0	0	45	114	6	0	0	0	0	0	189	1.34
21.6	22.0	0	0	0	0	0	0	0	0	34	111	5	0	0	0	0	0	164	1.17
22.0	22.4	0	0	0	0	0	0	0	0	45	86	1	0	0	0	0	0	146	1.04
22.4	22.8	0	0	0	0	0	0	0	0	40	61	4	0	0	0	0	0	135	0.96
22.8	23.2	0	0	0	0	0	0	0	0	45	66	5	0	0	0	0	0	106	0.75
23.2	23.6	0	0	0	0	0	0	0	0	37	54	2	0	0	0	0	0	113	0.80
23.6	24.0	0	0	0	0	0	0	0	0	23	49	1	0	0	0	0	0	92	0.65
24.0	24.4	0	0	0	0	0	0	0	0	26	32	2	0	0	0	0	0	74	0.53
24.4	24.8	0	0	0	0	0	0	0	0	22	27	1	0	0	0	0	0	59	0.42
24.8	25.2	0	0	0	0	0	0	0	0	22	12	1	0	0	0	0	0	50	0.36
25.2	25.6	0	0	0	0	0	0	0	0	28	21	0	0	0	0	0	0	34	0.24
25.6	26.0	0	0	0	0	0	0	0	0	26	14	0	0	0	0	0	0	49	0.35
26.0	26.4	0	0	0	0	0	0	0	0	27	10	0	0	0	0	0	0	40	0.28
26.4	26.8	0	0	0	0	0	0	0	0	11	5	0	0	0	0	0	0	37	0.26
26.8	27.2	0	0	0	0	0	0	0	0	12	6	0	0	0	0	0	0	16	0.11
27.2	27.6	0	0	0	0	0	0	0	0	14	5	0	0	0	0	0	0	18	0.13
27.6	28.0	0	0	0	0	0	0	0	0	14	5	0	0	0	0	0	0	19	0.14

TABLE B-14 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

WINTER - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) > =<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
28.0 28.4	0	0	0	0	0	0	0	0	10	3	0	0	0	0	0	0	13	0.09
28.4 28.8	0	0	0	0	0	0	0	0	7	8	0	0	0	0	0	0	15	0.11
28.8 29.2	0	0	0	0	0	0	0	0	8	3	0	0	0	0	0	0	11	0.08
29.2 29.6	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	4	0.03
29.6 30.0	0	0	0	0	0	0	0	0	3	4	0	0	0	0	0	0	7	0.05
30.0 30.4	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	5	0.04
30.4 30.8	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	5	0.04
30.8 31.2	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	3	0.02
31.2 31.6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.01
31.6 32.0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0.01
32.0 32.4	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	4	0.03
32.4 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 33.2	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0.02
33.2 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 34.0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0.02
34.0 34.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.4 34.8	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.01
34.8 35.2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.01
35.2 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	110	52	20	20	7	18	19	16	1064	5724	2554	3061	610	183	219	395	14072	
PERCENT FREQ	0.78	0.37	0.14	0.14	0.05	0.13	0.14	0.11	7.56	40.68	18.15	21.75	4.33	1.30	1.56	2.81		100.00
AVERAGE WIND SPEED (M/S)	4.7	2.6	1.8	1.9	2.0	2.0	2.3	2.3	21.4	16.8	12.0	10.0	7.0	3.2	3.9	7.2		

TABLE B-14 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

ANNUAL – 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
0.0	0.4	13	3	3	2	0	0	1	0	40	48	0	0	0	0	0	1	111	0.07
0.4	0.8	0	0	0	0	0	0	0	0	46	26	1	0	0	0	0	0	73	0.04
0.8	1.2	0	0	0	0	0	0	1	0	24	32	0	0	0	0	0	0	57	0.03
1.2	1.6	5	9	14	9	13	9	5	11	32	36	18	20	10	18	6	5	220	0.13
1.6	2.0	648	711	899	872	843	554	373	355	475	568	671	764	737	615	553	542	10180	6.20
2.0	2.4	691	736	869	941	929	607	378	363	420	523	865	793	756	624	587	614	10696	6.51
2.4	2.8	436	465	485	620	744	422	222	229	273	366	593	618	553	394	322	358	7100	4.32
2.8	3.2	386	351	397	546	569	339	160	134	230	348	475	541	465	346	266	240	5793	3.53
3.2	3.6	281	236	305	411	522	229	108	97	177	329	479	594	506	324	246	226	5070	3.09
3.6	4.0	252	189	249	359	454	203	109	66	152	309	449	564	473	257	200	192	4477	2.72
4.0	4.4	216	172	229	400	448	232	87	62	141	282	532	651	485	221	159	156	4473	2.72
4.4	4.8	185	117	231	463	570	165	64	48	112	294	593	802	473	211	150	145	4623	2.81
4.8	5.2	125	90	204	486	633	205	37	23	116	273	646	930	448	190	132	140	4678	2.85
5.2	5.6	101	62	224	484	621	198	37	21	99	248	681	962	455	184	103	125	4605	2.80
5.6	6.0	115	40	151	550	676	174	30	21	103	304	690	985	471	173	74	100	4657	2.83
6.0	6.4	97	31	108	583	731	117	24	15	108	358	714	1050	525	141	65	78	4745	2.89
6.4	6.8	85	33	86	574	856	141	34	14	112	414	773	1129	597	140	59	111	5158	3.14
6.8	7.2	93	31	69	546	823	144	21	10	117	428	758	1095	618	124	52	94	5023	3.06
7.2	7.6	79	23	60	573	807	134	10	12	134	505	794	1114	634	132	37	98	5146	3.13
7.6	8.0	66	13	69	634	805	97	16	6	171	566	816	1158	750	118	27	93	5405	3.29
8.0	8.4	54	2	51	627	699	73	12	13	144	595	791	1250	669	103	43	87	5213	3.17
8.4	8.8	50	2	51	612	727	43	11	8	135	643	796	1197	626	120	10	69	5100	3.10
8.8	9.2	40	2	33	588	655	42	10	11	139	702	819	1106	625	93	14	88	4960	3.02
9.2	9.6	35	3	19	622	535	44	7	4	159	726	773	1103	554	88	17	94	4771	2.90
9.6	10.0	32	1	14	492	439	36	4	4	164	736	715	1034	531	64	6	76	4348	2.65
10.0	10.4	28	0	14	465	394	21	3	3	204	768	597	919	507	43	12	75	4053	2.47
10.4	10.8	14	0	14	464	370	17	0	2	211	756	612	875	488	39	11	49	3921	2.39
10.8	11.2	16	0	9	400	322	10	1	3	220	774	539	781	443	38	8	67	3631	2.21
11.2	11.6	7	0	9	357	298	2	2	0	206	683	428	727	375	38	3	51	3186	1.94
11.6	12.0	5	0	4	322	275	0	1	0	250	757	481	629	322	30	4	40	3120	1.90
12.0	12.4	0	0	7	295	261	0	0	1	265	661	427	541	296	35	2	35	2825	1.72
12.4	12.8	13	1	5	254	252	0	0	2	233	702	442	449	281	24	4	30	2690	1.64
12.8	13.2	2	0	4	197	217	0	0	0	278	672	412	366	237	24	1	24	2443	1.49
13.2	13.6	0	0	8	139	164	0	0	0	276	650	325	256	171	26	0	36	2051	1.25
13.6	14.0	1	0	5	93	108	0	0	0	273	655	383	184	168	17	1	14	1902	1.16

TABLE B-15

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA.

ANNUAL - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) >=	<	348 / 11	11 / 33	33 / 56	56 / 78	78 / 101	101 / 123	123 / 146	146 / 168	168 / 191	191 / 213	213 / 236	236 / 258	258 / 281	281 / 303	303 / 326	326 / 348	TOTAL FREQ	PERCENT FREQ
14.0	14.4	4	0	2	74	78	0	0	0	252	640	288	164	128	17	0	23	1670	1.02
14.4	14.8	1	0	0	45	45	0	0	1	262	548	266	130	83	12	1	17	1411	0.86
14.8	15.2	0	0	1	22	37	0	1	0	245	545	245	99	60	14	0	17	1286	0.78
15.2	15.6	0	0	0	20	30	0	0	0	216	531	210	71	53	4	0	10	1145	0.70
15.6	16.0	3	0	0	11	28	0	0	0	173	524	160	54	42	6	0	3	1004	0.61
16.0	16.4	0	0	0	6	15	0	0	0	156	478	152	50	29	4	0	8	898	0.55
16.4	16.8	0	0	0	4	19	0	0	1	151	538	149	19	25	0	0	1	911	0.55
16.8	17.2	0	0	0	2	10	0	0	0	129	517	120	24	10	0	0	2	814	0.50
17.2	17.6	0	0	0	1	10	0	0	0	131	491	93	17	6	0	0	1	750	0.46
17.6	18.0	2	0	0	1	13	0	0	1	106	508	103	11	2	1	0	3	748	0.46
18.0	18.4	1	0	0	0	8	0	0	0	95	486	90	9	2	1	0	0	694	0.42
18.4	18.8	0	0	0	1	11	0	0	1	73	399	56	13	2	0	0	2	559	0.34
18.8	19.2	0	0	0	0	8	0	0	0	69	459	69	3	3	0	0	0	612	0.37
19.2	19.6	0	0	0	1	5	0	0	0	61	400	50	3	2	0	0	2	523	0.32
19.6	20.0	0	0	0	0	5	0	0	0	74	368	39	1	1	0	0	0	488	0.30
20.0	20.4	0	0	0	0	0	0	0	0	72	430	38	1	0	0	0	1	543	0.33
20.4	20.8	0	0	0	0	1	0	0	0	62	379	30	0	0	0	0	0	473	0.29
20.8	21.2	0	0	0	0	0	0	0	0	69	315	24	0	0	0	0	0	409	0.25
21.2	21.6	0	0	0	0	0	0	0	0	72	276	18	0	0	0	0	0	366	0.22
21.6	22.0	1	0	0	0	0	0	0	0	61	253	12	0	0	0	0	0	328	0.20
22.0	22.4	0	0	0	0	0	0	0	0	43	200	10	0	0	0	0	0	253	0.15
22.4	22.8	0	0	0	0	0	0	0	0	61	195	11	0	1	0	0	0	268	0.16
22.8	23.2	0	0	0	0	0	0	0	0	50	170	5	0	0	0	0	0	225	0.14
23.2	23.6	0	0	0	0	0	0	0	0	59	155	4	0	0	0	0	0	218	0.13
23.6	24.0	0	0	0	0	0	0	0	0	55	134	2	1	0	0	0	0	192	0.12
24.0	24.4	0	0	0	0	0	0	0	0	39	110	4	0	0	0	0	0	153	0.09
24.4	24.8	0	0	0	0	0	0	0	0	48	111	1	0	0	0	0	0	160	0.10
24.8	25.2	0	0	0	0	0	0	0	0	50	79	1	0	0	0	0	0	130	0.08
25.2	25.6	0	0	0	0	0	0	0	0	48	50	0	0	0	0	0	0	98	0.06
25.6	26.0	0	0	0	0	0	0	0	0	46	49	0	0	0	0	0	0	95	0.06
26.0	26.4	0	0	0	0	0	0	0	0	40	48	0	0	0	0	0	0	88	0.05
26.4	26.8	0	0	0	0	0	0	0	0	46	25	0	0	0	0	0	0	71	0.04
26.8	27.2	0	0	0	0	0	0	0	0	23	32	0	0	0	0	0	0	55	0.03
27.2	27.6	0	0	0	0	0	0	0	0	18	17	0	0	0	0	0	0	35	0.02
27.6	28.0	0	0	0	0	0	0	0	0	21	14	0	0	0	0	0	0	35	0.02

TABLE B-15 (CONTINUED)

JOINT FREQUENCY DISTRIBUTION OF WIND SPEED AND WIND DIRECTION AT LIVINGSTON, MONTANA

ANNUAL - 46 METER LEVEL

WIND DIRECTION RANGE (DEGREES)

WIND SPEED RANGE (M/S) > =<	>= 348 < 11	11 33	33 56	56 78	78 101	101 123	123 146	146 168	168 191	191 213	213 236	236 258	258 281	281 303	303 326	326 348	TOTAL FREQ	PERCENT FREQ
28.0 28.4	0	0	0	0	0	0	0	0	11	7	0	0	0	0	0	0	18	0.01
28.4 28.8	0	0	0	0	0	0	0	0	11	10	0	0	0	0	0	0	21	0.01
28.8 29.2	0	0	0	0	0	0	0	0	10	4	0	0	0	0	0	0	14	0.01
29.2 29.6	0	0	0	0	0	0	0	0	2	4	0	0	0	0	0	0	6	0.00
29.6 30.0	0	0	0	0	0	0	0	0	3	4	0	0	0	0	0	0	7	0.00
30.0 30.4	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	6	0.00
30.4 30.8	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	5	0.00
30.8 31.2	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	3	0.00
31.2 31.6	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.00
31.6 32.0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0.00
32.0 32.4	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	4	0.00
32.4 32.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
32.8 33.2	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3	0.00
33.2 33.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
33.6 34.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.0 34.4	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0.00
34.4 34.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
34.8 35.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.2 35.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
35.6 36.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.0 36.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.4 36.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
36.8 37.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.2 37.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
37.6 38.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.0 38.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.4 38.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
38.8 39.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.2 39.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
39.6 40.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
TOTAL FREQ	4182	3323	4902	15168	17083	4258	1769	1542	9461	27256	21338	25860	15698	5039	3175	4249	164303	100.00
PERCENT FREQ	2.55	2.02	2.98	9.23	10.40	2.59	1.08	0.94	5.76	16.59	12.99	15.74	9.55	3.07	1.93	2.59	100.00	
AVERAGE WIND SPEED (M/S)	3.9	3.0	3.7	7.0	6.8	4.2	3.3	3.1	11.6	12.4	8.4	7.7	7.3	4.9	3.6	5.2		

TABLE B-15 (CONTINUED)

ATTACHMENT A

SITE OPERATOR'S LOGBOOK AND MAINTENANCE CHECK SHEETS